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Vulnerable aging in flooded households and adaptation to climate change in cities in Latin America: the case of Monterrey

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Resumen

Hay una limitada comprensión del reto del envejecimiento de la población en América Latina ante los peligros del cambio climático. La investigación analiza los factores que determinan la vulnerabilidad de la población envejecida en hogares afectados por inundaciones recurrentes en la ciudad de Monterrey (México) y su capacidad de adaptación a los peligros. La metodología se basa en un análisis de los datos de una encuesta, así como el uso de un SIG a escala de colonia. Los resultados indican que la vulnerabilidad de envejecer en el lugar (vivienda y colonia) afectado por inundaciones recurrentes se explica por los factores de presión ambiental, competencia funcional, envejecimiento avanzado, exclusión social y capacidad de gestión del riesgo. La distribución de la población envejecida vulnerable muestra una mayor concentración en las colonias del centro urbano, demográficamente envejecidas, y en las colonias de alta marginación social de la periferia de Monterrey. Se concluye que las deficiencias detectadas en la gestión del riesgo y la limitada capacidad de adaptación de las personas mayores a las inundaciones recurrentes favorecen su vulnerabilidad ante el cambio climático.

Palabras clave: Envejecimiento en el lugar, inundaciones, vulnerabilidad, cambio climático, gerontología ambiental.

Abstract

Vulnerable aging in flooded households and adaptation to climate change in cities in Latin America: the case of Monterrey

There is a limited understanding of the challenge of an aging population in Latin America to the dangers of climate change. The research analyzes the factors that determine the vulnerability of the elderly population in households affected by recurrent floods in the city of Monterrey (Mexico) and its adaptability to hazards. The methodology is based on an analysis of survey data and the use of GIS at neighborhood. The results indicate that the vulnerability of aging in place (housing and neighborhood) affected by recurrent floods is explained by the factors, environmental pressure, functional competence, advanced aging, exclusion social and capacity for risk management. The distribution of vulnerable elderly population shows a greater focus on neighborhoods demographically aging city center and suburban neighborhoods highly marginalized of Monterrey. It is concluded that the deficiencies in risk management and limited adaptability of the elderly to recurrent floods favors their vulnerability to climate change.

Key words: Aging in place, flooding, vulnerability, climatic change, environmental gerontology.

Introduction

Climate forecasting points out that in the XXI century extreme hydrometeorological phenomena (tropical cyclones and extreme rainfall) will be the more common and increase their dangerousness (Cutter *et al.*, 2003; Fekete, 2009) mainly in developing regions, where the population ages concentrated in problematic urban environments (Bankoff, 2003) and where there is limited capability to manage risk associated with growing vulnerability and poor capability to adapt to challenges posed by climate change.

Various international agencies, such as HelpAge (2007), mention the importance of acknowledging the threats from the environment in a context of climate change, as well as the adaption capability of aging populations. Indeed, in the XXI century in cities in Latin America and the Caribbean an increase in the ageing of vulnerable population is foreseen from the growing climate emergencies, such as floods and heatwaves (Artiles and Sangabriel, 2012), overflowing the governments' limited response capacity (Beniston, *et al.*, 1997, Etkin and Ho, 2007). However, there is scant knowledge of the climate implications on urban demographic aging and also about the relation between risky environments and the capacity of the vulnerable elderly to adapt to the growing natural hazards (Pekovic *et al.*, 2007; Johnson, 2008; Loke *et al.*, 2012).

Recent research underscore the need to know how the elderly face natural disasters and how they are preparing for the challenges of climate change, as this collective is highly vulnerable and suffers to a large extent its adverse effects (Packauri and Reisinger, 2007; De Toma, 2009; Carter *et al.*, 2014). This way, a number of studies have focused on finding out how the increase of natural hazards associated with climate change (Webb, 2006; Packauri and Reisinger, 2007) are affecting the aging populations. Indeed, the increase in the mortality of the population of 60 years of age and older linked to natural dangers (floods, heatwaves) has been documented; albeit, there is scarce knowledge on the increase in this collective's morbidity associated with the combination of environmental, social and health-care factors (Roce, 2008; Åström *et al.*, 2011). In like manner, some work indicate the limited survival capacity of the elderly in the face of extreme weather conditions, due to increasing health problems, reduced mobility (competence levels and disability), isolation, social exclusion and problems to access social and health-care services (O'Neill *et al.*, 2009; Aubrecht *et al.*, 2013).

The literature indicates accumulated evidence that the physical-social environment has a decisive influence on the vulnerability of the elderly when they face natural dangers (Haq *et al.*, 2013; Gamble *et al.*, 2013; Tillett, 2013). However, there is limited knowledge on how to age in the place and adapt to the challenges of climate change. In recent decades, the relevance of designing sustainable social policies aimed to favor aging in the place, through the adaption of their environmental contexts to the goring needs of this social group (Andrews and Phillips, 2005; Sánchez-González, 2015). In the same vein, some researches have underscored the importance of being aware of the factors that determine the spatial experience of aging in the place and also the need to study the pressure from the environment on aging (Byrnes *et al.*, 2006), as it conditions residential satisfaction, mainly of he elderly with fewer functional capabilities and therefore greater environmental challenges.

The background of aging before risk management

Lately, a number of catastrophic floods, such as New Orleans (2005), Villahermosa (2007) and Monterrey (2010), have revealed the governmental incapacity to manage risk and assist the victims, mainly the elderly (Pekovic *et al.*, 2007; Rothman and Brown, 2007). This way, it has been indicated that the implemented governmental actions unveiled the ignorance on how manage risk before an aging society within a context of climate emergency (Rosenkoetter *et al.*, 2007; Sánchez-González, 2008). In spite of the advances in developed countries in post-disaster attention for the mentally-challenged elderly (Claver, 2013), still distinguishable is the need to enquire on the groups with high dependency levels (Wahl *et al.*, 2012). Moreover, little is it known about vulnerability associated with population aging in the context of climate change, mainly in cities in developing countries such as Mexico and in general, in Latin America and the Caribbean (Dutton, 2013; Sánchez-González and Chávez, 2016).

In recent decades, the literature has approached the concept of vulnerability reading climate change (Patt *et al.*, 2009), being the target of criticism owing to its conceptual and methodological deficiencies (Füssel, 2010). Precisely, some experts (Chakraborty *et al.*, 2005; Lavell *et al.*, 2012) have intended to empirically contribute to its study, perfecting the definition of vulnerability as a propensity to being negatively affected (IPCC, 2012). In Latin America and the Caribbean such term has been broadly used in studies, however it has been frequently utilized in the wrong way to refer to poverty, marginalization and social exclusion. In this research, vulnera-

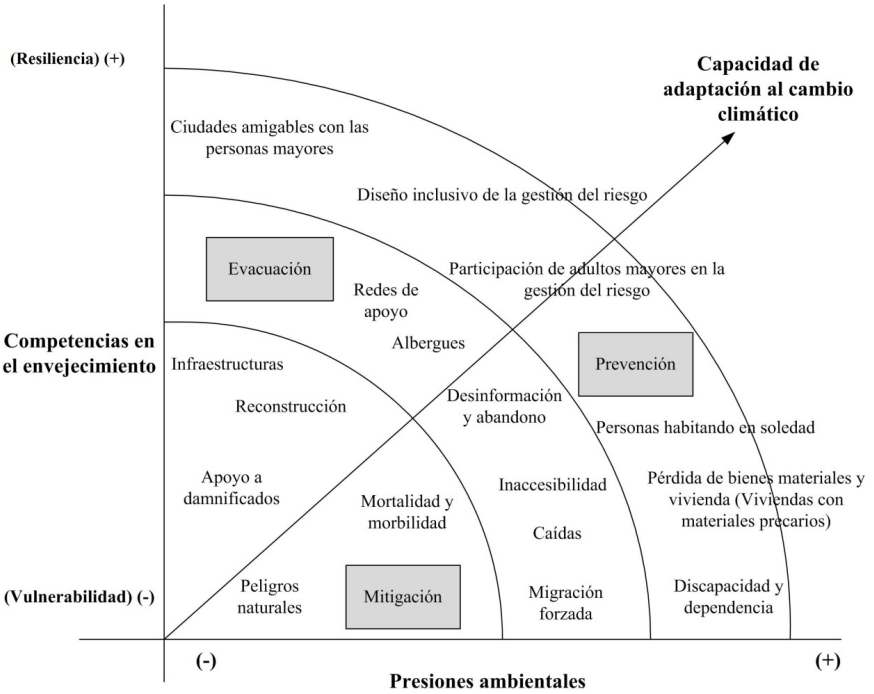
bility is understood as "the level of risk, faced by an individual or family, of losing their lives, properties or assets or their livelihood (how they make their living) in the face of a possible catastrophe" (Sánchez-González y Egea, 2011).

Scientific publications have documented the effects of climate on the population via individual events, such as Hurricane Katrina's floods in August 2005 (Johnson, 2008). However, there is little research that systematically approaches the possible long-term consequences of floods for the elderly and the adaption processes of this collective in the face of hazards associated to climate change (Adams *et al.*, 2011; Sánchez-González and Chávez, 2016).

Lawton and Nahemow (1973) by means of their ecological model of aging, mention that the individual adapts to environmental pressures, mainly when the environment supports the individual's physical needs, and when the person and the environment are in balance. However, the absence of security, as an attribution of the environment of the elderly (De Toma, 2009; Geboy *et al.*, 2012), can potentiate the perception of dangerousness and with it aggravate their vulnerability (figure 1). Recent studies underscore the importance of acknowledging the factors that determine vulnerability and resilience in aging, in view of propitiating strategies of the elderly to adapt to the environment facing the increasing environmental pressures (Byrnes *et al.*, 2006; Haq *et al.*, 2010). In like manner, it is underlined the importance of generating friendly and safe physical-social environments for the elderly, as well as propitiating strategies aimed at fostering their resilience and proactivity (OMS, 2007; Sánchez-González and Chávez, 2016).

The present research contributes to the knowledge on vulnerability of people who age in places (households and neighborhoods) that have been recurrently affected by floods caused by various events in recent years, which has allowed us to approach the long-term consequences on the adaption capacities of the elderly to the challenges posed by climate change in Latin America and the Caribbean. Precisely, the city of Monterrey has been selected as a case study, as it is the third Mexican city with the most aged population and it is exposed to increasing natural dangers (tropical cyclones and extreme rainfall) associated with global warming (Adame, 2013).

Figure 1. Vulnerable aging adaption to climate change



Source: own elaboration. Adapted from Lawton and Nahemow (1973); De Toma (2009).

The objective of this research is to analyze the factors that determine the vulnerability of the elderly in the place (household or neighborhood) affected by the Monterrey's recurring floods and thir capability to adapt to the hazards of climate change. This way, in order to approach the object of study, three questions were proposed: i) which are the main socio-demographic characteristics of of the population of 60 years of age and older in the households affected by recurring floods in the city of Monterrey? ii) Which are the determinant factors of the vulnerability of aging in the place (household and neighborhood) affected by recurrent floods in the city of Monterrey? And, where is the aged population vulnerable to floods and limited capacity to adapt to the growing hazards of climate change in the city of Monterrey?

Regarding, the second question, the starting hypothesis was produced: H1, the vulnerability of aging in the place (household and neighborhood) affected by floods is determined by the degree of environmental pressure

(exposition of the physical-constructed environment), the level of functional competence of the elderly (fragility and disability) associated to advanced aging, social exclusion and the need to improve the cities' risk management. We also discuss the role of institutions in charge of providing support to the elderly affected by floods and the need to improve risk management in Latin Ameirica and the Caribbean from promoting the participation of the elderly and improve the adaption of their physical-social environments in the face of climate change challenges.

Methodology

The methodology is based on a multivariate analysis (factorial analysis by main components and cluster analysis) of data from a survey to people of 60 years of age and older affected by recurrent floods, as well as the development of a Geographic Information System (GIS) at a neighborhood scale.[1]

The survey was designed to gather information on the vulnerability of the elderly from a multidimensional perspective. The utilization of data from our own survey allows us to approach the sociodemographic characteristics of aged people in households affected by recurrent floods at neighborhood level in the city of Monterrey, and also to find out their perception on the vulnerability to floods. In this regard, firstly, a previous test was made on 10 people, aged sixty or older, in areas with flooding risk, in view of validating the questions and answers on the questionnaire to be applied. As a result, we obtained the definitive questionnaire applied at the households in July 2012. This way, the final sample was not a probabilistic one, it comprised 195 people of 60 years of age and older at households who had been affected by two or more floods within the last ten years. This way, such sample distributed by gender and age group. Field work was conditioned by the problem of perception of grave insecurity and mistrust from the elderly, which limited the sample, and particularly the participation of people older than 75 years with disability and dependence.

Variables

For data analysis a data matrix disaggregated at the level of the 195 respondents was generated, it consisted of 129 variables that were subject to a descriptive statistical analysis (frequencies, percentages, correlations) (table

1 In the study the cartography used at the scale of neighborhood is based on the shapes at Basic Geo-statistic Area provided by the National Institute of Statistics, Geography and Informatics (INEGI, 2010).

1). In the principal component factorial analysis, a data matrix disaggregated at the level of 75 neighborhoods was utilized; it had information on the 195 respondents. Such secondary data matrix comprised 11 variables that were selected following the literature (Webb, 2006; Sánchez-González, 2009) and associated to the following five dimensions: i) sociodemographic characteristics; ii) sort of coexistence; iii) competence level in health and functioning; iv) characteristics the physical environment (housing and neighborhood); and, v) rick management (table 2).

Analysis method

The analysis of data from the survey was performed using Microsoft Excel, SPSS and Statistica. Also a method to analyze and interpret the data, the technique of Factorial analysis by principal components and Varimax rotation was applied (Knox, 1974). Hence, five components that explain 67.7 percent of the variance were obtained; these represent high communalities (> 0.5252) and coefficients for each of the analyzed variables (table 2).

The socio-spatial distribution of the vulnerability index of the elderly in households affected by recurrent floods in Monterrey was established following Cluster analysis, which enables grouping relatively homogeneous neighborhoods from the same characteristics of vulnerability.

Also, in the production of the dendrogram, expressed in Euclidean distances, the factorial scores of the five principal components were utilized and five clusters were obtained; these, also called neighborhood typologies, had homogeneous characteristics related to the socio-spatial vulnerability of the aged population in the study areas. Also, the obtained clusters were cartographically represented by means of a Geographic Information System (GIS) using ArcGIS, which allowed analyzing the uneven spatial distribution of vulnerability of the elderly in households affected by floods at the level of neighborhood in Monterrey.

The metropolitan area of Monterrey is one of the most important Mexican cities in Latin America and the Caribbean, characterized by the significant concentration of population of sixty years of age and older, as well as by its high exposition to extreme hydrometeorological phenomena such as tropical cyclones (Alex, 2010) and extreme rainfall, with an origin in the Gulf of Mexico, a region especially affected by the effects of climate change (Adame, 2013).

Table 1. Sociodemographic characteristics of the population of 60 years of age and older in households affected by recurrent floods. Monterrey. 2012 (frequencies and percentages)

Variable		N	(%)
Gender	Man	67	34.4
	Women	128	65.6
Age	60-74 years	140	71.8
	75 and older	55	28.2
Form of coexistence	Spouse and children	139	71.3
	Other relatives	2	1.0
	Alone	54	27.7
Schooling	No schooling	21	10.8
	Elementary	118	60.5
	Secondary / high school	32	16.4
	Technical studies	18	9.2
	University studies	6	3.1
	Not knows / no answer	31	15.9
Monthly income	Low (under 2500 MXN)	106	54.4
	Mid (between 2500 - 4999 MXN)	49	25.1
	High (5000 and more MXN)	9	4.6
	Not knows / no answer	1	0.5
Heal care services (entitlement)	Not entitled to health care services	46	23.6
	Entitled to health care services	148	75.9
Physical limitation or disability	Mobility	56	28.7
	Visual	41	21.0
	Hearing	11	5.6
	No problems	115	59.0
Need of help to perform everyday tasks	Needs help	49	25.1
	No need	146	74.9
Information on shelters	Awareness of shelters in the neighborhood	180	92.3
	Unawareness of shelters in the neighborhood	15	7.7
Information on evacuation	With information about evacuation	142	72.9
	With no information about evacuation	53	27.1
Evacuation in case of flooding	People who evacuated the household due to flooding	49	25.1
	People who did not evacuate the household due to flooding	146	74.9
Institutional support in case of flooding	Received institutional support	58	29.7
	Did not receive institutional support	137	70.3
Total		195	100.0

Table 2. Rotated factorial matrix (normalized varimax rotation). Principal component analysis for data aggregated by neighborhood. Monterrey 2012

N	Variable	Description	Communalities	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
		Sociodemographic characteristics						
1	V75YM	% of people over 75	0.661412	-0.014603	0.107376	0.795987	-0.125879	0.015086
2	VANALFF	% of people with no elementary studies	0.657274	0.015275	-0.448686	0.647047	0.132670	0.139462
3	VINGRES	% of people with very low incomes (<2500 MXN/month)	0.740810	0.091575	0.038900	0.148613	0.824624	0.169764
		Forms of coexistence						
4	VSOLAS	% of people living alone	0.595604	0.453841	0.041869	0.280125	0.545250	0.110054
		Competence level in health and functioning						
5	VDISCAPA	% of people with disability	0.785087	0.047042	0.761022	0.295621	-0.302201	-0.158119
6	VMOVILID	% of people who have suffered falls in the household	0.775066	-0.036588	0.839529	-0.182190	0.188996	-0.002558
		Characteristics of the physical environment						
7	VVSERV	% of people in damaged households (services, structures)	0.693752	0.754065	-0.083738	-0.043241	0.044785	-0.338009
8	VACOLONI	% of people in affected neighborhoods (accessibility services)	0.730499	0.795201	0.072529	0.249797	0.173350	-0.021115
		Risk management						
9	VNEVACUA	% of people who did not evacuated in floods	0.709733	-0.027824	0.015852	-0.040268	-0.119685	0.832323
10	VDALBERG	% of people who ignore the existence of shelters	0.525160	0.641992	0.143522	0.275976	0.126762	-0.013311
11	VSAPOYOG	% of people who did not receive institutional support	0.572226	-0.125934	0.051938	0.122146	0.014746	0.733847
	Expl.Var			18.73	15.26	13.65	10.61	9.44
	Prp.Totl			0.17	0.14	0.13	0.11	0.13

Data in standardized percentages aggregated according to neighborhood.

Factors: 1) Environmental pressure; 2) functional competence; 3) advanced aging; 4) social exclusion; 5) capacity to manage risk.

Source: own elaboration.

In the research the study areas were selected from the location of the neighborhoods in areas at risk of recurrent flooding in the Metropolitan area of Monterrey (figure 2) and which presented a high rate of demographic aging at neighborhood level (INEGI, 2010). As a result, 75 neighborhoods with high relative presence of aged population by risk of recurrent flooding in Monterrey were selected, which is observed further in the text in the rotated factorial matrix.

Results

Sociodemographic characteristics of aged people affected by recurrent floods

Among the main sociodemographic characteristics of the population of 60 years of age and older at households affected by recurrent floods in the city of Monterrey, it is noticed the prevalence of two thirds of women before men and the presence of only 28.2 percent of people of more than 75 years of age and older.

Regarding schooling, six out of ten aged people had finished elementary studies, almost one in three had accomplished secondary or higher education, and one in ten had not had any schooling, mainly women older than 75 years.

Also, almost four out of five aged people do not work, compared with the 19 percent declared keeping a formal job, and mainly an informal one (with no social security or heal care). In the same vein, 75.9 percent were entitled to social security, however one in four did not have social security, mainly women over 60.

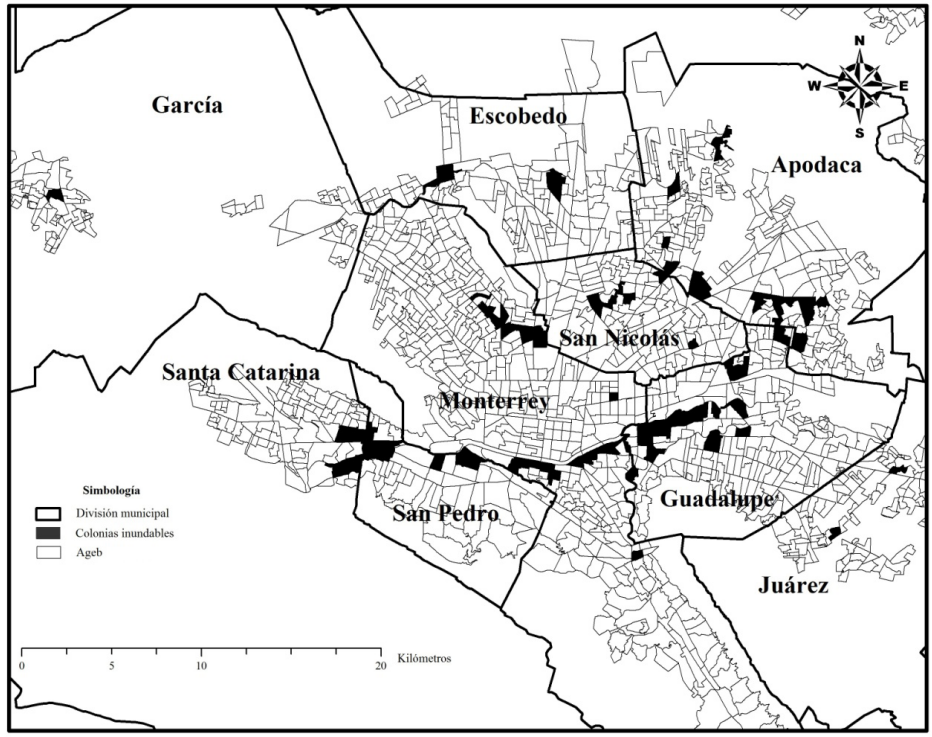
In like manner, 54.4 percent of the respondents received a wage under 2 500 MXN (1847.1 US[2]), and only 4.6 percent received wages over 5000 MXN (374.3 USD). In this regard, a greater vulnerability is noticed among aged women, whose variable correlates negatively with continue working (-0.419**)[3] and positively with disability (0.259*) and living alone (0.245*). Also, there is high vulnerability among people between 75 and older, whose variable correlates with the presence of physical limitation or disability (0.263*) and absence of complete studies (0.240*). Moreover, vulnerability is insistently present among disabled aged people, whose variable correlates with falls in the house (0.393**), absence of complete studies (0.364**) and lack of retirement pension (0.359**).

2 In June 2012, when the questionnaire was applied the exchange rate was 13.36 MXN per 1 USD (Banco de México, 2012). http://www.banxico.org.mx/

3 **The correlation is significant at a 0.01 level (bilateral).

*The correlation is significant at a 0.05 level (bilateral).

Figure 2. Location of the study areas. Metropolitan Area of Monterrey. 2012



Source: own elaboration.

Coexistence at the households of the elderly is characterized by the prevalence of married people, while widowed individuals are mostly women older than 75 (31.3 percent). Likewise, 27.8 percent lived on their own, for more than 5 years then, and mainly women over 60. So, the perception of solitude is very high in this collective and 11.8 percent admitted that their children did not visited them or seldom did it. Then, 40.5 percent stated feeling sad frequently or sometimes, mostly people who lived on their own and did not go out (isolation). Here it is noticed that the variable solitude correlates with variables sadness (0.720**) and not leaving the house (0.281*). In this regard, changes in the family structure are increasing the risk of solitude and abandonment of people of the elderly, as well as compromising the traditional model of informal help to dependency (Spielauer, 2005), which in the region means serious challenges to a society that ages in a growing context of climate emergency and limited capacity of the governments.

Regarding the competence level in health care and functioning, physical limitations or disability, these appeared in more than a third of the aged population (34.9 percent), being it most evident among women of 75 years and older with mobility (25.1 percent) and vision problems (21 percent). As well, independence levels were high, since only one in four needed help (25.1 percent), mainly women of over 60 years. Likewise, 45.1 percent of the elderly had fallen in their house, which in most of the cases had become heavier physical dependence, mainly women of 75 years and older with disability problems, and associated with the existence of architectonic barriers, slippery materials or lighting problems.

The physical-constructed environment of the elderly, such as housing and the neighborhood, becomes a protagonist in aging, mainly in situations of climate emergence, since they condition the stages of prevention, evacuation and mitigation. This way, most of the aged adults lived in their own houses (86.7 percent), before those who rented a relative's property. Besides, acquiring their housing showed to be older than 30 years in a half of the respondents. Too, regarding the typology of the house of the elderly, the sort of prevailing housing has one story (94.9 percent), which increases the risk of losing appliances and personal property to floods, facing the impossibility of taking them to a second floor. More so, it is noticeable that only 7.7 percent of the people who experienced a fall in their house had made a modification, compared with 92.3 percent who had not been able to carpet it, which increases the risk of new falls, mainly at the moment of evacuation. All of this makes the household an unsafe place, whose vari-

able correlates with disability (0.334**), affectation to the neighborhood services due to floods (0.274*) and problems in public transport (0.267*). In the same line, it is noticed that the variable affectation to housing (basic services and infrastructure) correlates with solitude (0.304**) and living alone (0.230*).

In the perception of the neighborhoods, a half of the elderly pointed out that their main problem was street insecurity, followed by floods, accessibility (sidewalks in poor conditions[4], streets blocked[5] and deficient public transport) and lack of public spaces (green areas, community centers). These data corroborate that the main concern of the respondents was the grave insecurity,[6] mainly linked to organized crime, even above the recurrent floods that affect their environment. Also, closer attention to the public spaced was asked both to the elimination of architectonic barriers, which hamper accessibility, and to the need to increase areas for recreation and leisure, which favor social relations and build supportive networks. Here, it is noticed that the variable affectation to neighborhood services by floods correlates with the variables problems of solitude (0.308**) and people who regularly use public transport (0.266*).

Regarding risk management, information becomes determinant at times of emergency. This way, almost all the respondents recognizes the existence of a center (community center, public school) that is set up as a shelter in emergencies in the neighborhood, mainly women older than 75. Here, we notice that the variable use of shelter in the neighborhood correlates with people with disability (0.474**) and people who have suffered falls (0.291*). As well, 72.9 percent of the aged adults was informed on the need to evacuate their house facing hazard from floods, mainly via authorities (police, firefighters and military) (33.2 percent), friends and neighbors (18.6 percent), relatives (12.6 percent), and the media (television and radio) (8.5 percent); while a third of the elderly was not informed about the

4 In the city of Monterrey municipal governments overlook the maintenance of the sidewalks, delegating this responsibility to the proprietors of the buildings, which usually causes neglecting and or private appropriation of the public space this circumstance limits mobility and conditions accessibility for pedestrians and especially for people with disabilities or challenged, main in emergency situations.

5 In municipalities such as San Nicolás de los Garza, in the face of insecurity, some municipal governments have blocked streets in some neighborhoods by placing protective fences, which has meant the division of the neighborhoods. This measure has not reduced delinquency indexes, however keeping social networks has been hindered (contacts between neighbors from different neighborhoods), as well as blocked evacuation routes and the attention to the elderly in case of an emergency.

6 In 2010, the metropolitan area of Monterrey recorded 1 305 homicides, i.e., 30.8 murders per 100 thousand inhabitants, placing in the 47th place among the most violent cities in the world (Consejo Ciudadano para la Seguridad Pública y la Justicia Penal, 2013), http://www.seguridad-justiciaypaz.org.mx/. Consulted on 12/Jan/2015.

needs to evacuate, mainly women of 60 years and older who live on their own (13.3 percent). Another interesting aspect underscores that 74.9 percent of the elderly affected by floods had remained at the household and was not evacuated, essentially women of 60 years of age and older who live on their own; while 25.1 percent had evacuated their house temporarily and had moved in most of the cases to a relative's house. Precisely, it is recorded that the variable evacuation correlates negatively with people with problems of solitude (-0.253*) and sadness (-0.243*). Likewise, problems were detected in the phase of risk mitigation referring governmental help for the elderly affected by the floods. In fact, 70.3 percent of the elderly in households affected by floods stated that authorities did not do much during the floods, contrasting by 29.7 percent that did receive support, mainly donation of food (13.8 percent), clean sewers (storm drain) (8.7 percent), economic donation (8.2 percent), medical attention (4.6 percent), donation of basic articles (4.1 percent), donation of furniture and appliances (3.6 percent) and transport to evacuate (2.6 percent). By the same token, it was noticed that the variable government support for the victims negatively correlated with people with sadness problems (-0.262*).

Analysis of the vulnerability of aging in a place affected by floods

As a result of the factorial analysis by principal components five factors were obtained, which explained 67.7 percent of the total variance after varimax rotation and which presented relatively high communalities (table 2).

The first factor, environmental pressure (degree of exposure of the physical-constructed environment), explains 18.7 percent of the total variance and comprises three variables corresponding to two dimensions: variable VACOLONI (percentage of people in effected neighborhoods) and VVSERV (percentage of people in housing affected in its basic services and with structural damage) both corresponding to the dimension Characteristics of the physical environment, and the variable VDALBERG (percentage of people who ignore the existence of shelters) related to the dimension Risk management. This way, the principal component indicates high environmental pressure which the physical-constructed environments (household and neighborhoods) of the elderly, a circumstance aggravated by recurrent floods, which reflect the high vulnerability and poor adaption capability of this collective, as well as the limited risk management capability at institutional level to mitigate flood hazard. Also, the factor agrees with the proposal of a number of authors (Byrnes *et al.*, 2006; Sán-

chez-González, 2009), who indicate that aged people can live in places (households and neighborhoods) with limited habitability and incompatible with the changing needs of aging, negatively contributing to their physical and mental wellbeing.

The second factor, *Functional competence (level of fragility and disability)*, expresses 15.3 percent of the total variance and is composed of two variables of the dimension Competence level in Heath care and functioning such as VMOVILID (percentage of people who have suffered falls at home) and VDISCAPA (percentage of people with disability). Here, in this principal component distinguishable is the problem of low level of functional competence in aging, determined from the degree of fragility (risk of falls at home) and the degree of disability of physical limitation, mainly in a context of heavy environmental pressure from their surroundings exposed to floods. This factor agrees with that expressed by Lawton and Simon (1968), who mentioned that the capacity to adapt decreases over age and with disability in various environments: structural environment, social support and coping strategies (Cvitkovich and Wister, 2001).

The third factor, Advanced aging, represents 13.6 percent of the variance and it is explained from two variables of the sociodemographic dimension: V75YM (percentage of people over 75 years[7]) and VANALFF (percentage of people with no elementary studies). This principal component relates the group of elderly with problems of access to study (illiteracy), which has conditioned access to formal labor markets and the situation of social exclusion at old age (absence of pensions and entitlement to health-care services) (Sánchez-González, 2015), it also supposes a vulnerability factor in the face of disasters (reading of prevention brochures, understanding of the evacuation signals) (Webb, 2006).

The fourth factor, Social exclusion, accounts for 10.6 percent of the variance and reveals the importance of variables VINGRES (percentage of people living on very low incomes) of the sociodemographic dimension and VSOLAS (percentage of people living on their own) of the dimension forms of coexistence. Hence, this component reflects the serious problem of marked social exclusion in aging associated both to low economic incomes and living alone, which increases the vulnerability of the elderly in situations of climate emergency (economic capacity to adapt and rehabilitate their environments, help capability in case of disaster). In this respect,

7 It is worth pointing out that the variable age la variable was disaggregated into two categories or groups of age (60 to 74 years and 75 and older), being the one of 75 and older that which statistically reached more representativeness in the variance.

some studies (Sánchez-González and Egea, 2011) indicate that social exclusion is a determinant factor of vulnerability in aging, whish is usually associated to poverty and solitude. This factor as well can reflect the problem of lack of social networks, which stresses the problem of solitude and lack of support in emergencies (Cramm *et al.*, 2012).

The fifth factor, Risk capacity management, contributes with 9.4 percent of the variance and it is explained from the variables of the dimension risk management, VNEVACUA (percentage of people who did not evacuate in floods) and VSAPOYOG (percentage of people who did not receive institutional support). This way, this principal component indicates the limited risk management capacity at institutional level both in the stages of evacuation and mitigation to support the affected elderly.

Spatial distribution of the aged population vulnerable to floods and with limited adaption capability to hazards from climate change in Monterrey

In view of propitiating a better risk management in the face of the challenges of climate change, it is important to find out the location of the aged population and with limited adaption capability (lower resilience) before the increasing natural dangers (floods) in the city of Monterrey. Hence, in the cluster analysis the criterion of likelihood from the correlation coefficient applied to the factorial scores of the five main components at neighborhood scale was utilized.

Also, the dendrogram, based on Euclidian distances, allowed grouping the neighborhoods in five typologies of representative areas of the study (figures 3 and 4).

Typology 1 mainly comprises outskirt neighborhoods with less marked aging, high immigration, high social marginalization, important prevalence of disability and very low socioeconomic level (*Independencia*, *Cañada Blanca* and *Riberas del Río*), as well as some peripheral ones with middle socioeconomic level (*Villas de San Miguel*, *Residencial La Noria* and *Santa Rosa*). Here, population under 75 years with disability prevails (41.3 percent), who has experienced a fall at home (48 percent).

As well, 24 percent of the elderly experiences difficulties to access medical services, related with problems in the quality of service, distance and cost of transport. Regarding vulnerability before floods, only 16 percent of the elderly evacuated the house in case of floods, mainly in *Independencia* and *Morelos* neighborhoods. Likewise, in the neighborhoods of typology 1, four out of five aged adults reported that they did not receive any support

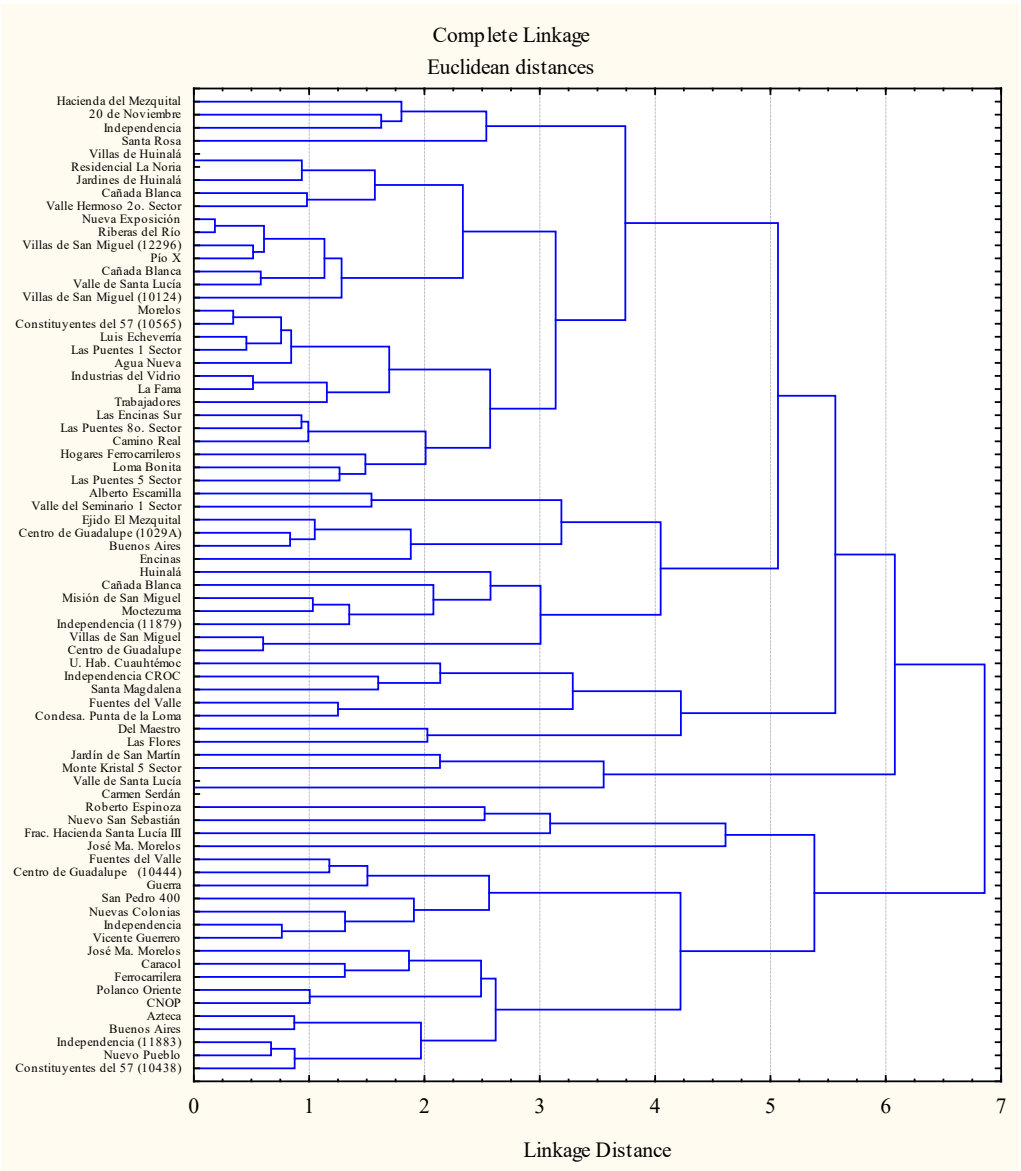
from the authorities and only 21.3 percent received support, mainly in *Independencia*, *Morelos* and *Villas de San Miguel* neighborhoods.

Typology 2 is characterized by neighborhoods with less marked aging (lower presence of people of 75 years of age and older) and high migration, also located in the southwest periphery of the city, where residential and industrial land use mix; these neighborhoods present a very low socioeconomic level (*Santa Magdalena* and *Unidad Hab. Cuauhtémoc* in the municipality of Santa Catarina), and also middle and high socioeconomic level (*Fuentes del Valle* in the municipality San Pedro Garza García). Neighborhoods in typology 2 also present public spaces complicated for pedestrians, due to the presence of architectonic barriers and the perception of the problem of insecurity, which explains that only 13.3 percent displaced on foot to visit friends or relatives. As regarding vulnerability before floods, one in two aged people did not receive support from governmental institutions.

Typology 3 predominantly comprises neighborhoods with less marked aging, moderate aging, these are located in the northwest of the city, close to Topo Chico Hill (Valle de Santa Lucía), where distinguishable is the presence of old self-constructed housing inhabited by elderly people with low socioeconomic level and disability problems (22.2 percent) (*Jardín de San Martín* and *Monte Kristal 5º Sector*), as in the neighborhood *Valle de Santa Lucía*. There is also that one in three aged adults does not use hospitals or used them with lower frequency, associated to the perception of deficiencies in the quality of service of health-care services. Another relevant characteristic of this neighborhood typology is that in spite of the continual presence of floods, the aged adult population stated conformed that they will face the lack of institutional support and largely rejected evacuating their houses in case of an emergency. In this regard, the main affectations expressed by the aged population was lack of storm drain, lighting and street cleaning problems, and the need of economic support requested by the elderly (55.5 percent).

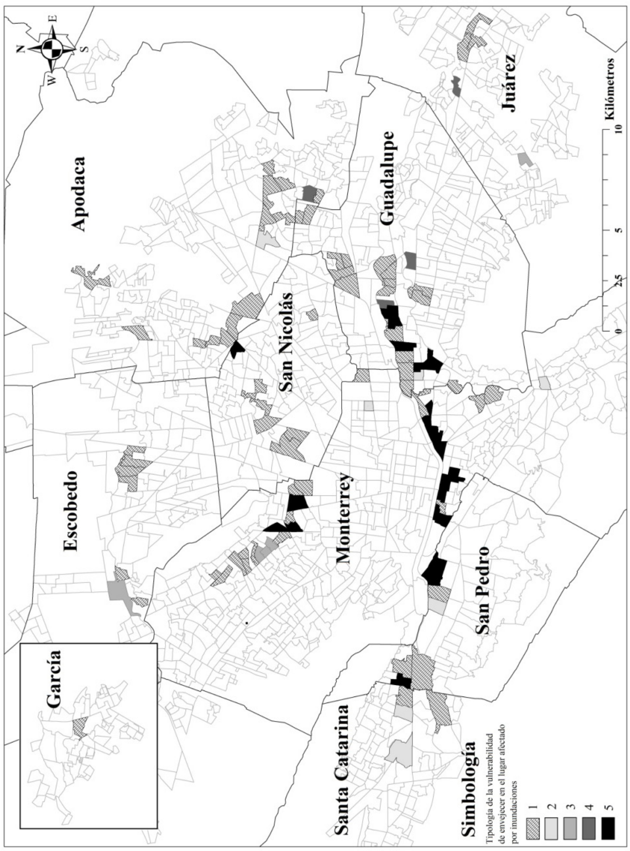
In typology 4, neighborhoods with noticeable aging are identified (high relative presence of people of 75 years of age and older), moderate migration and disability problems, located southeast of the city, with prevailing low socioeconomic level (*Hacienda Santa Lucía III, José María Morelos* and *Nuevo San Sebastián*) and poor urban consolidation (absence of basic services and equipment). This way, neighborhoods in typology 4 recorded high relative presence of people with physical limitations or disabilities (66.6 percent) and people who had experienced a fall at home (50 percent)

Figure 3. Dendrogram of factorial scores of the principal components of vulnerability according to neighborhoods. Monterrey, 2012 (Euclidian distances)



Source: own elaboration.

Figure 4. Spatial distribution of the typologies of ageing vulnerability in the place affected by floods in Monterrey. 2012 (typologies of cluster analysis)



Source: own elaboration.

(*Hacienda Santa Lucía III* and *Roberto Espinoza*). Also, a lower relative presence of aged people living on their own (16.6 percent), which may be related with the high crowing level recorded, as well as the need to share the house with children and other relatives. Regarding the vulnerability of the aged population facing floods, only 16.6 percent has received some sort of governmental support (food, medical assistance), despite the affectation to their housing (structure problems, basic services) and neighborhoods (interruption of basic services) was greater than other neighborhood typologies.

Finally, typology 5 presents neighborhoods with moderate aging, low migration and high relative presence of people living on their own, mainly in the urban center of the city (*Centro de Guadalupe*, *Guerra*, *Nuevas Colonias* and *Vicente Guerrero*), where older established settlements with middle-low socioeconomic level are found. This population's sociodemographic level is completed with a low disability rate (14.2 percent), even though with a sizable aged population who has experienced a fall at home (35.8 percent), which might increase the disability rate in the future, mainly among people who live on their own (35.7 percent) and facing the impossibility of improving the building. This way, in this typology of neighborhoods, green areas and hospitals are located, this favors their utilization (78.5 percent) (*Centro de Guadalupe*). As regards vulnerability of the elderly at risk of flooding, it stated that they did not received governmental support facing the emergency and that only 14.3 percent evacuated their house after the flood and went to live with some relative. Likewise, the main problems of the households affected were damage to structure (50 percent) and the interruption of basic services (25 percent) and in the case of the neighborhoods, the main problems were suspension of basic services (71.4 percent).

Discussion and conclusions

The experts notice the scarce knowledge of the sociospatial implications of the physical environment on the aging of the population (Wahl, Iwarsson and Oswald, 2012), mainly in dangerous contexts (Geboy *et al.*, 2012) and urban scenarios exposed to climate emergencies (Webb, 2006; HelpAge, 2007).

In Latin America, the lack of urban planning and risk management make acuter the problems of habitability in cities such as Monterrey, restricting the possibilities to age in the place, and also the capacity to adapt

to the challenges of climate change. Likewise, the vulnerability of the population of 60 years and older is associated with growing problems of social exclusion, disability and dependence (Sánchez-González, 2015), which is aggravated by not-so-friendly and unsafe physical-social environments for the elderly, which negatively affect their physical and psychological well-being, as it reduces their autonomy on where and how to live.

The results of the main socio-demographic characteristics of the population of 60 years of age and older in households affected by recurrent floods in the city of Monterrey, reveal the high social vulnerability of this collective and its limited capacity to adapt to natural hazards associated with climate change. Indeed, the most vulnerable group comprises aged women, people of 75 years of age and older and people with physical limitations and disabilities, as they present marked social exclusion linked to the poor education, restricted access to labor market, lack of retirement pension and low incomes, also limited access to social and health-care (health care insurance) services. In the same vein, the literature indicates that the elderly are more vulnerable and suffer to a larger extent the effects of extreme climate events (Packauri and Reisinger, 2007; Luszczynska, *et al.*, 2009; Jia *et al.*, 2010).

This way, the study reveals there is an inverse relation between the possibility of evacuating in the presence of a flood and age, disability and dependence. All the same, in aging to the extent age increases, the levels of functional competence decrease and the prevalence of functional dependence and the risk of falls increases (Manrique-Espinoza *et al.*, 2011), which makes evacuation difficult and limits the possibilities of adapting to the growing natural hazards associated with the processes of global warming.

As we approach the social sphere of the elderly, changes in family structure, lack of social networks and limited governmental support (social, care and health services) contribute to increase vulnerability, as they present isolation problems, linked to the fact of living on their own and not leaving their houses, which aggravates the perception of solitude and sadness. Likewise, this vulnerable collective is at greater risk of abandonment associated with lack of supports (formal and informal), both to address the needs of everyday life linked to dependence issues and also in emergency situations (Sánchez-González and Egea, 2011). Here, were stated the hypothesis that scant evacuation of the elderly related with the existence of environmental risks (fear of falling, architectonic barriers, insecurity, floods) and the limited availability of strategies and assets to

face them (lack of supportive networks, solitude, isolation, trust no one), which makes their vulnerability acuter. This way, some authors (Cramm *et al.*, 2012) mention there is evidence that the existence, closeness and availability of supportive networks contribute to a greater social cohesion and associate with proactivity of the elderly (Lawton, 1989). However, such proactivity can be conditioned in environments that lack security, as supportive networks are difficult to maintain, as well as the processes of adaption and belonging.

The analysis of the characteristics of the physical-constructed environment of the elderly, such as housing and neighborhood, reveal important habitability problems and security that condition the process of aging in the place. Hence, in the housing of the aged adult prevail old buildings, many of them self-built, single story and with the presence of architectonic barriers (steps, slippery materials and lighting problems), which aggravate the exposition to anthropic (falls in the house) and natural hazards (flood affectations).

Some studies (Knodel and Chayovan, 1997; Gómez and Peñalver, 2007; Suelven *et al.*, 2010) have pointed out the relation between the falls and the increment in disability and dependence, a circumstance that becomes extremely relevant in environments exposed to danger. Also, the property regime of the house and the limited economic resources of the elderly, and the lack of institutional help, restrict the possibilities of modifying the buildings for according to the changing needs of aging and alleviate the damage caused by floods (structural problems and supply of basic services). As in other studies (Salgado-Gracia and Olivera-Pueyo, 2005), the impossibility of improving the household means that most of the elderly who have suffered a fall return to the place and once again face the environmental dangers (architectonic barriers, floods), even though with fewer competences (deteriorated health, hip fractures, disability, dependence) and greater vulnerability. Here it is worth underscoring that we have stated the hypothesis that remaining in the place (housing, neighborhood) even under conditions of lack of habitability can be a beneficial strategy to face the catastrophe compared with those who opt for or are forced to move from such place (Granbom *et al.*, 2014). However, our results advice against such strategy and propose a change of residence in thos environmental contexts with high levels of environmental pressure (architectonic barriers that increase the risk of falls, floods) because of their negative effects on the functional competences of the aged population and their limited capability to adapt to the growing natural hazards linked to climate

change. The habitability problems of the neighborhoods for the elderly are associated with severe problems of street insecurity linked to organized crime, growing flood risks and limited risk management. This, way other problems perceived in the neighborhoods are the presence of architectonical barriers (sidewalks in poor conditions, blocked streets), deficient maintenance of public services (public transport, lighting, security) and the lack of facilities (health-care centers, hospitals, public spaces, green areas) and infrastructure (storm drain). Here, in order to favor healthy aging, the elderly underscored the need to improve access and use of heal-care and hospital services, mainly owing to deficiencies in the quality of the service, the distance to medical centers, and the cost and quality of public transport. This way, the lack of habitability of the neighborhoods has its inception in their historic evolution, being placed in floodable areas of the urban center and the periphery, where old irregular settlements that later were regularized are identified.

The results register important deficiencies in risk management in the city of Monterrey, mainly as they are houses and neighborhoods that have flooded before, and since no amendments have been made to ameliorate the damage (infrastructures) and prevent future hazards and the discussable prevention program aimed at vulnerable aged populations and their families (disinformation, lack of emergency drills, ignorance and blocks of evacuation routes by the involved parties), as well as scarcity of resources to assist the growing aged population in case of hazard (transport adapted for evacuation, trained staff, shelters) and support for the victims in the mitigation stage.

As regards the explanatory factors of vulnerability of aging in the place (housing and neighborhood) affected by recurrent floods in the city of Monterrey, by means of the principal component analysis it is verified the hypothesis that vulnerability is determined by the degree of environmental pressure (exposition of the physical-constructed environment), functional competence level of the elderly (fragility and disability), associated to advanced aging, the degree of social exclusion and the level of governmental capacity of risk management. In this regard, starting from the ecological model of competence (Lawton and Nahemow, 1973), we can state that the adaption capability of the elderly in the face of the increase in hazards (floods) from climate change is established by the combination of the subject's specific competence level and the degree of environmental pressure, which is determined by both hazard exposition (architectonic barriers, floods) and social (poverty, social exclusion) and environmental factors

(lack of risk management, limited social policies) which foster vulnerability. Adaption capability and belonging to the quotidian place (Rowles and Watkins, 2003) can also be altered after the succession of dangerous events (floods, falls, violence), as well as ways to face it, determined by the interpretative relationship of the elderly with their daily environments. Here, it is verified that factors such as disability, solitude, sadness abandonment and distrust in the institutions increase the social vulnerability of aged people in the face of floods and limits their capability to adapt to the challenges of global warming.

As a result of the cluster analysis, it is observed an uneven spatial distribution of the vulnerable aged population with limited adaption capability to increasing hazards (floods) of climate change, showing heavier concentration in the urban center neighborhoods, demographically aged and in the neighborhoods of the periphery of Monterrey, characterized by their lesser aging, high marginalization and acute social marginalization. Indeed, in the urban center vulnerability is associated with aged people who live on their own and have little support; while in the periphery, vulnerability is explained by the presence of aged people at high risk of social exclusion and in areas of marked social marginalization, where returned migrant aged population is found, which presents poor resilience to face natural hazards (Chávez and Sánchez-González, 2012). In like manner, it is worth mentioning that in the face of flood risk and also due to the absence of governmental supports for the elderly in those neighborhoods most vulnerable and exposed.

Various researches (Wahl *et al.*, 2012) distinguish the importance of analyzing the factors of the physical-social environment that contribute to age actively and healthily in the place. In the case of the study of the attributes of the daily and hazardous environments, and those exposed to floods, it has been possible to approach the comprehension of changes in the environment and their implications in the continual adaption processes of the elderly (Granbom *et al.*, 2014). The consequences are usually traumatic for this vulnerable collective, which must develop strategies to face usually with considerable personal and social efforts to rebuild the places of belonging.

The design of social and risk-management policies must incorporate the comprehension of the complexity of social-health attention, as well as mechanisms of the elderly to adapt to the challenges of climate change, owing to their physical limitations, the structure and location of their houses and their specific needs of hygiene and health care, among others

(Rothman and Brown, 2007; Fernández-Bilbao, 2011; Oven *et al.*, 2012). Likewise, one of the challenges of the studies will be to understand the uncertainties of climate change by means of assessing the possible direct effects (economic damage, direct casualties) and mainly the indirect effects on the population (health problems, loss of income sources, disappearance of social and supportive networks) on the elderly in zones affected by floods in large Latin American cities (Sánchez-González and Chávez, 2016).

In years to come, future research focused on understanding the effects of climate change on the health of the elderly should propitiate different statistical analyses on mortality and morbidity from a longitudinal perspective and will be based on new hospital records that have to include specific information on the various physical-social environments (housing, neighborhood) of he aged population, as well as past climate events.

Other interesting research line states the need to understand the effects of time over aged people, as well as its incidence on risk management (prevention stage) and especially, in the capabilities to adapt to climate change. This way, it is important to contribute to explain the multidimensional relation of the physical-social environment with the aging individual, derived from changes over time (Wahl and Lang, 2003).

Having reached this point, it is necessary to reflect on the discussable role of governmental institutions in charge of providing support the elderly, as well as risk management due to the lack of prevention before global wring effects in the region. In this regard, it is outraging to think that regional authorities continue obviating and minimizing the graveness of the demographic and environmental challenges in the XXI century, delay the setting into motion of priority measures before the effects are irreversible. Because of this, the design of friendly environments and gerontological planning of risk management which enable the empowering and active participation of the elderly in case of climate emergency. Precisely, it will be of the utmost importance to raise awareness of the various actors on fostering sustainable lifestyles, as well as the huge challenges to adapt to an aging society to climate change issues.

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