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Article

Adaptation model to climate change in the traditional homes of the Weenhayek people in Bolivia

Juan Marco Rojas-Molina[1], Libys Martha Zúñiga-Igarza[2], Reyner Pérez-Campdesuñer[3], Yandi Fernández-Ochoa[4], Gelmar García-Vidal[3], Alexander Sánchez-Rodríguez[4,*]

[1] University of the West of England, Bristol BS161, UK
[2] Universidad de Holguín. Faculty of Engineering, Holguín 80100, Cuba
[3] Faculty of Law, Administrative and Social Sciences, Universidad UTE, Quito 170507, Ecuador
[4] Faculty of Engineering Sciences and Industries, Universidad UTE, Quito 170507, Ecuador
*** Corresponding author:** Alexander Sánchez-Rodríguez, alexander.sanchez@ute.edu.ec

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Abstract: The affectations caused by extreme events of natural origin such as droughts and floods in traditional homes in the province of Gran Chaco, in Bolivia, are frequent. These aspects compromise the habitat of the populations that occupy them, as is the case of the original Weenhayek people, as an alternative for the improvement of the human habitat of this town. Through theoretical and empirical methods, five variables used for the development of the adaptation model were determined, from the bases of planned adaptation as a component of urban-territorial resilience, in search of an improvement of socio-environmental systems in the face of the effects of climate change, exemplified in the Weenhayek native people. The model establishes the improvements of traditional dwellings, from a current trend of deterioration to one of preservation, conservation and growth in the Weenhayek culture, through various features, such as: Respects the cultural design of the house that integrates local patterns of the environment, ecosystem and contemporary construction elements without affecting its image, the materials and construction techniques used are of a traditional nature, but with contemporary elements that improve their application, durability, stability, as an articulated construction system, commits governments in all instances to the technical-constructive study of the rural areas of the human settlements of the Weenhayek people, and establishes a starting point towards new studies focused on native peoples.

Keywords: climate change; human habitat; urban-territorial resilience; environment; ecosystem; contemporary construction

1. Introduction

Climate change because of global warming appears to be the main crossroads worldwide (González Ordóñez, 2016). Specifically, the Plurinational State of Bolivia is a country with a high index of sensitivity to climatic effects (climate change), where the climate depends on the disposition of the height of its surface (Redes Chaco, 2022). Within this accelerated process of modification of climatic conditions, indigenous communities are the most fragile, which causes an exodus from rural settlements to urban settlements, as is the case of the Weenhayek in Bolivia, since, in addition to compromising their environment, there is the abandonment of their customs in their ancestral lands (Rojas Molina and Zúñiga Igarza, 2023a).

The greatest environmental effects in the area where the Weenhayeks live are caused by the overflow of the Pilcomayo River, which causes floods that last for days in nearby areas, affecting the usual functioning of their homes, undermining walls,

dragging the materials that compose them, among others (Rojas Molina and Zúñiga Igarza, 2023b). At the same time, high temperatures and constant heat waves often cause people to abandon their homes for higher places, with an abundant supply of water, among others. Traditional houses are the most problematic to maintain accepted habitability patterns in their construction materials used, design and location, so that they increase the risks of extreme natural phenomena present in each territory and/or region. This is also influenced by social inequality, lack of knowledge, the degree of willingness of the community and the level of practice from the spheres of government, among other elements (González-Gaudiano and Maldonado-González, 2017). On the other hand, there are limitations in terms of literary records on the particularities of these dwellings in the Bolivian Chaco area (Rojas Molina, 2022).

There are other studies analyzed on adaptation to climate change in various countries in favor of the adaptability of housing to the new social-economic-cultural conditions that involve characteristics of their architecture and functionality. Rojas Molina (2022) made comparisons and analyzed several studies on the subject. In this sense, studies on housing in Mexico corroborate the ideas of the weakness of housing in the face of climate change. For example, the study with the theme "ABC-34—The current construction of houses in Hermosillo and its adaptation to the climate by passive means" (Marincic et al., 2015) shows the deficient adaptation to the climate by passive means of housing. It further details that developers market such passive designs to improve thermal conditions inside. Another study in Mexico is the "Proposal for a comprehensive model for the sustainable evaluation of social housing" (García Rodríguez et al., 2015) seeks the evaluation of sustainability in social housing, based on the characteristics and predominant construction systems. However, it is only an analysis of sustainability models in the market, which does not represent a proposal for a comprehensive systemic model, since by defining that the main variant is the type of construction system, it only makes a partly technical assessment of it independently without inquiring into the existing interdisciplinarity. Also presented in this country is the research, "Proposal for sustainable social housing for hot climates. application in the city of Chetumal" (Quivén Franco, 2016); which seeks to rescue the integration of the characteristics of the vernacular constructions of the region as constructive parameters due to the sustainability it presents, incorporating uses and customs of contemporary users.

Similarly, Rojas Molina (2022) analyzed cases in Peru, others such as "Evaluation of the sustainability of construction materials in the construction of homes in the district of Huacho" (Medina Zavaleta, 2019) highlights that climate is only a characteristic of the environment to establish the appropriate construction materials in a house for an area or region. Also, he reviewed the study "Design of bioclimatic houses for high Andean areas" (Cóndor, 2017) establishes that existing houses are technically deficient, since they do not provide the same conditions of habitability as when they were built, so he emphasizes that the use of the natural resources of the place for a house as the solution and (or) response to achieve the sustainability of their habitability today. He also argues that contemporary parameters such as earthquake-resistant design, optimal sanitary conditions, among others, must be added. In the same way, he reviewed the research "Environmental readaptation of housing in human settlements: The case of Villa Sol, Piura" (Guerrero, 2017) emphasizes the importance

of environmental adaptation in the assessment of the technical state of housing and the existing shortage in various regions, this being an emerging and latent need, which results in the deterioration and abandonment of these homes.

However, there were limitations in the integration of environmental, economic and sociocultural components reflected in the dwellings of other sociocultural groups that would allow the conservation of their habitat and customs, which constitutes a gap for the realization of this research, taking into account that there is little of indigenous groups similar to the case study of the Weenhayek in the scientific-technical literature.

The traditional homes of the Weenhayek in the Gran Chaco region in Bolivia reflect the loss of their constructive cultural traits, through the displacement of their living area and the occupation of homes built with materials called new or contemporary (zinc sheet metal, plastic, canvas, among others) (Rojas Molina and Zúñiga Igarza, 2021a). Added to this is the lack of plans on the part of the regulatory entities belonging to the municipal and national government in reference to: Public policies that involve a plan for territorial environmental regulation and ordering; preventive environmental conservation plans; and housing programs that preserve, promote and execute houses with cultural construction characteristics with materials and techniques typical of the original peoples. The autochthonous inhabitants of the Chaco region (Weenhayek) remained for hundreds of years without depleting natural resources, but the compulsive entry that responded to the context of world consumption had the consequence of lowering the environment that surrounds them and as a direct consequence they displaced the indigenous peoples to unknown and deep places in the area (Barúa and Rodríguez, 2009).

This research focuses on the application and analysis of scientific research methods (theoretical-empirical) to reveal the incident variables and parameters in climatic affectations, to propose improvements in its components, focused on the approach of a housing model. Said model is oriented to the adaptation of the current environmental conditions in the region, which entails the conservation, improvement and preservation of the traditional Weenhayek houses in the province of Gran Chaco in Bolivia, according to their social, cultural and constructive features as an alternative for the improvement of the habitat of said traditional constructions. It is also the result of scientific and technological research called “Model of adaptation to climate change in the traditional homes of the Weenhayek people in Bolivia” (Rojas Molina and Zúñiga Igarza, 2021b).

The problems reflected so far are due to various factors such as the loss of uses and customs, the displacement of their territories, the lack of adaptation of their designs to the new environmental conditions; conservation policies; adaptability of their construction techniques and materials, among others. These affectations have abruptly modified life within the Gran Chaco region, due to its particular geo-environmental characteristics, which implies the need for a conceptual management from a model of adaptation to climate change that responds to the improvements to the existing traditional constructions, in order to rescue, preserve and promote the constructive characteristics of this people as a means and way of life of the Weenhayek population (Rojas Molina, 2022).

A historical analysis allowed us to establish the development of this native group throughout the Chaco region, regardless of the territorial limits of the countries.

Montani and Combes de Guzmán (2018), reported that W'enaheyk (Weenhayek), comes from "Huennéyei", which is the self-designation of the Noctenes (current Weenhayek in Bolivia), for which W'enhayek is considered the self-appointment of the Bolivian Wichis, being also a word used by some Wichis that flow from the Pilcomayo as it passes through chaque soil. no. "Güisnay"—name of the Wichis of the middle Pilcomayo since the 19th century and "W'enaheyk" represent one and the same word. The Weenhayek are not only "different": they are "different people", "different Wichis", W'enhayek Wichi, where the identification through various terms of these original populations, as if they were different, respond to the interaction of churches, non-governmental action groups and governments (state) in recent years (Dejtiar, 2017; Ministry of Public Works, Services and Housing of Bolivia, 2015).

The Weenhayek population is disintegrated into several communities due to the loss of their territory that is conceived as an economic or social resource (Segura Guerrero et al., 2022), settled on the one hand on the banks of the Pilcomayo River (generally during the fishing season), and on the other in the centers of the rural communities surrounding the Pilcomayo River. These inhabit houses that use traditional construction techniques and materials (quincha, stick to pique) and contemporary (masonry, zinc sheets, among others); however, these have been mostly displaced by state housing programs that do not consider their cultural or traditional architectural aspects, which leads to the loss and progressive oblivion of their uses, customs and culture. Therefore, its original constructive characteristics of their homes are fading with the new contemporary policies of acculturation (Ministry of Public Works, Services and Housing of Bolivia, 2015, 2020).

Thus, these aspects allow us to appreciate that there is no harmonious correlation between what is built and the environment that surrounds it, which requires the constitution of theoretical-practical bases that allow the use of traditional materials and construction techniques, criteria of location and design of houses to adapt them, which help to guarantee the balance between economic growth, care for the environment and social well-being through the management of environmental risks, their adaptation to climate change; this evidences a literary gap on the subject associated with a specific indigenous group. To this end, a proposal is made for a model of adaptation to climate change in traditional constructions for the region that is studied representative of the cultures and traditions of the original Weenhayek people.

2. Materials and methods

The research presented continues the following course, which is based on the theoretical and empirical methods of information, which followed the common thread shown in **Figure 1**.

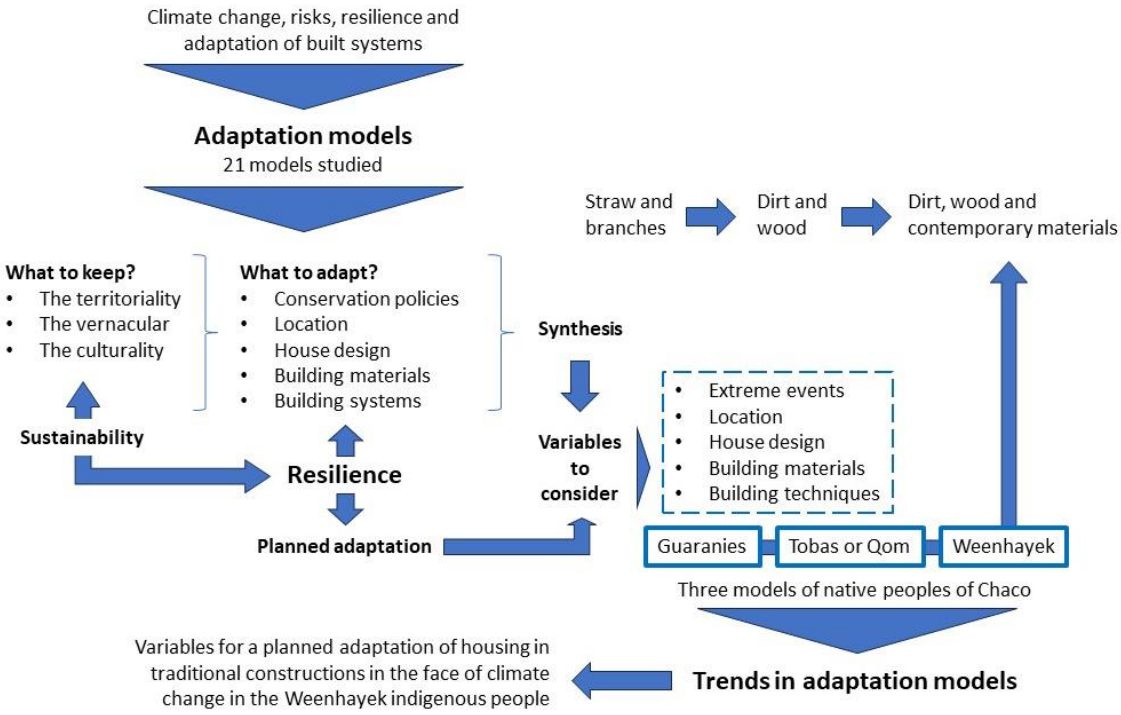

Figure 1. Research thread.

Note: Own elaboration.

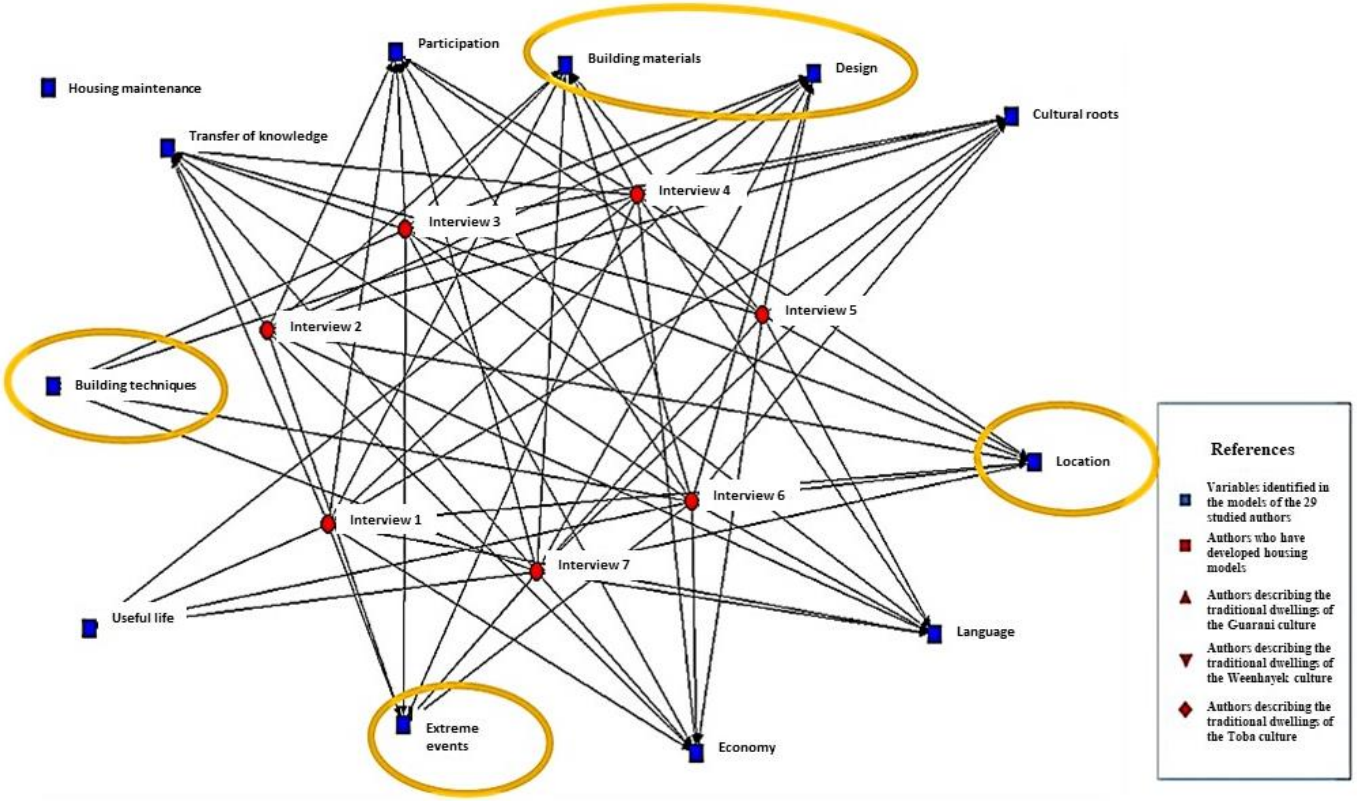

Figure 2. Variables determined with higher centrality.

Note: Own elaboration because of UCINET for Windows.

To this end, a systematization of housing in the face of climate change in various regions of the world was carried out, and it was determined that several authors

(Aguirre Le Vinson, 2017; Cóndor Aquino, 2017; Corbetta and Rosas, 2017; Cruz Zambrano and González Chacón, 2018; Garrido Herranz, 2018; González Couret and Véliz Párraga, 2016; Guerrero Ibáñez, 2017; Levinton, 2018; López and Tola, 2016; Maidana et al., 2020; Medina Zavaleta, 2019; Molina Márquez, 2019; Muñoz Márquez, 2016; Quivén Franco, 2016; Rojas Molina, 2022; Sumuano Martínez, 2016; Trillo, 2018; Villalba et al., 2017; Villegas Gómez, 2017; Zeballos Claure, 2019), involved variables that contribute to the adaptation of housing before climate change. Next, using the program UCINET for Windows: Software for social network analysis, 2002 allows as a result to determine the variables of greater centrality. **Figure 2** shows: location, extreme events, design, construction materials and construction techniques (Holgado, 2016).

Based on these variables, the result of applied scientific theoretical methods (analytical-synthetic, deductive-inductive, historical-comparative), together with empirical methods of the interview (structured in 22 applied questions), survey (structured in 24 questions) and scientific observation (consisting of 27 questions according to technical criteria) applied to native settlers for ten days. This process was characterized by obtaining reliable and direct data from the actors involved, which led to corroborate the variables established from the systematic analysis of the 29 authors (Rojas Molina, 2022).

For this, seven traditional or vernacular houses typical of the Weenhayek people were taken as a representative sample (made up of construction elements such as the foundations, walls, roof, floor and toilet areas, in which the materials used are characterized by the use of those of natural origin, some previously treated, such as the case of wood extracted from the environment they inhabit; the mud and branches used on the roof that insulates the temperature between the interior and exterior of the house, or the use of natural earth on the floor, and in other contemporary or current materials such as zinc sheet metal, bricks, canvas, which establish houses made with hybrid construction materials and techniques) located in the Weenhayek indigenous territory of the Gran Chaco recognized by Supreme Decree No. 23500. V.1992, which correspond to 30 percent of the 22 traditional character houses that the Weenhayek occupy in the jurisdiction of D'orbigny, in the rural area of the municipality from Yacuiba, Gran Chaco province.

In this territory there are 11 communities settled in the vicinity of the Pilcomayo river (Algarrobito Norte, Mora Vieja, La Bajada, Ebenezer, La Esquina, Sachapera, Mora Nueva, Mora Nueva Sur, El Brealito, El Nazario and El Sausal), which simultaneously represents 10% of the dwellings occupied by this town (the Weenhayek population in D'orbigny is considered to be 876 people distributed in 220 families), which They present a high degree of deterioration but with preserved elements of their culture. With these derivations for each applied technique (theoretical and empirical methods), the resulting information was triangulated in order to obtain agreed and integrated results (**Figure 3**), using the same UCINET for Windows program.

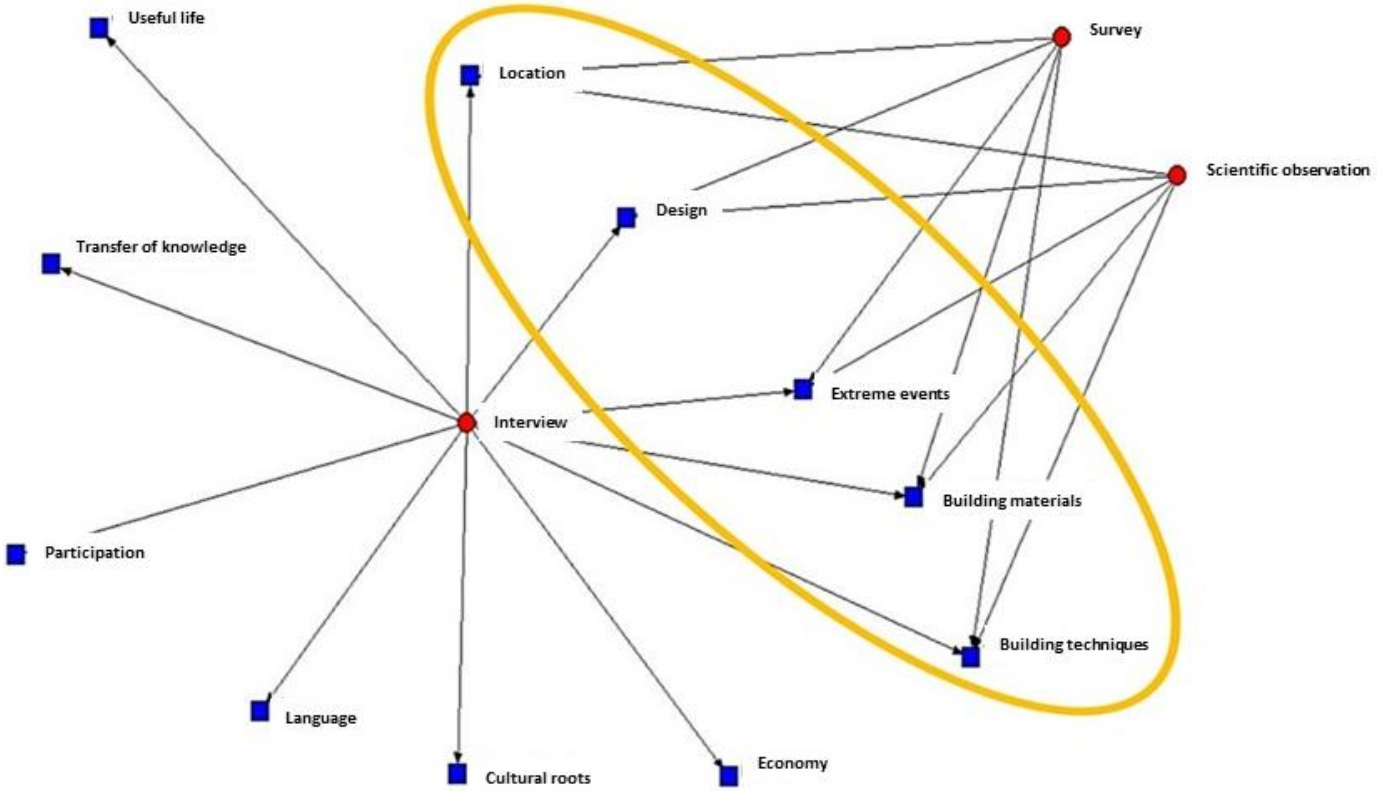

Figure 3. Correlation network of the variables integrating the used techniques.

Note: Own elaboration as a result of UCINET for Windows.

As a result, consensus was obtained on five variables with greater centrality in the network of relationships, which unite the aspects that have the greatest impact on the conservation of a house in the face of climate change, in contribution to the improvement of Weenhayek's original homes. These variables are: extreme events, location, housing design, construction materials, and construction techniques, where four of them (location, housing design, construction materials, and construction techniques) interact with the extreme event variables, helping to model a process that contributes to climate change adaptation in the traditional dwellings of the Weenhayek people in the Gran Chaco province of Bolivia. As a result of the modeling, **Figure 4** describes the process, where the location variable is a peculiarity of floods. The rest of the three variables are common to floods and droughts.

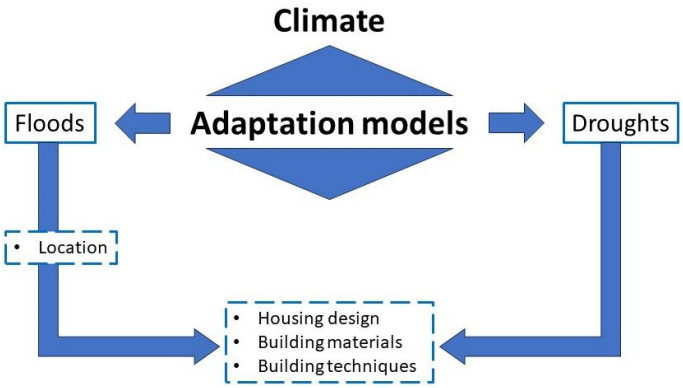

Figure 4. Adaptation model designed.

Note: Own elaboration.

As a theoretical method, modeling was also conceived to integrate, prioritize and offer as results a coherent process that helps to solve the problem posed. This modeling is conceived as a system; where it is necessary to locate the component parts or elements that are related to each other (functions, phases or stages of management), to identify the pattern that governs the relationships (functions, phases or stages of the approaches), to define the environment where the component parts or elements operate (hierarchical organization), to establish the cycle of events that identifies the process of the system (dimensions of the field of research), as well as the perception of a purpose seen as a whole (goal to be achieved), Rojas Molina (2022); which has led to a model of adaptation to climate change in the traditional dwellings of the Weenhayek indigenous people in Bolivia as a result.

3. Results and discussion

Climate change is a global problem of common interest that produces risks to society from climatic causes in an environment or region that cause threats such as floods, droughts, heat waves, variable winds, precipitation, frosts, hurricanes, desertification, among others. Conceptually, risk is articulated with vulnerability, exposure and threat. The threats in this research were determined by extreme natural phenomena of hydrometeorological origin ranging from extreme droughts to floods. While vulnerability has as components the exposure of traditional Weenhayek dwellings, considered as a disadvantage condition in the face of a threat; susceptibility is recognized as the degree of internal fragility to face a threat and receive a possible impact, in this case it is given by the way of constructing, the elements that compose it from the cultural patterns of the original Weenhayek people; and resilience as the last component of vulnerability, which is the ability of a material, mechanism or system to recover its initial state when the disturbance or threat to which it has been subjected has ceased. In this sense, it is evident that the elements of exposure and susceptibility make traditional Weenhayek dwellings very vulnerable, so the levels of recovery from the postulates of resilience are very low and scarce. That is why the work of improving and conserving these homes is demanded from the perspectives of resilience. In this sense, it was determined that, within resilience as a fundamental component in the reduction of vulnerability, it was possible to explain its functions as a derivation of a theoretical analysis around the subject through the conceptual analysis developed by 39 authors linked to research on traditional housing, climate change and risks (Rojas Molina, 2022). Therefore, resilience has as a quality the ability to adapt as an intrinsic property in terms of interdependencies that systems, resources, materials or objects must have as their main strength.

In 2015, the United Nations System treated this adaptive conception of resilience from two perspectives: autonomous adaptation defined as the adjustments made without external intervention of a material, resources, objects or system to recover its initial state when the disturbance or threat has ceased; and planned adaptation, the result of a conscious intervention by human beings as a sense of foresight, and precaution against any external effects that may affect them. Planned adaptation must be an instrument of territorial and environmental planning, to reduce risks, minimize vulnerability and achieve balanced development. This perspective of the planned

adaptive capacity of resilience has been the leitmotif used to conceive the improvement of the traditional dwellings of the Weenhayek indigenous people.

The susceptibility of Weenhayek houses to large extreme hydrometeorological events such as floods resulting from the overflow of the Pilcomayo River, damage the houses through filtration by accumulation of water, which accelerates the chemical reactions in the components of the natural construction materials used, which cause saturation of the construction materials used, wood rot, breakdown of the structure of the house, increase of fungi, wear of wall coverings, detachment of the construction materials used, among others. As for high temperatures and droughts, they produce the excessive drying of the earthy materials used in the construction of traditional houses that weaken the cohesion of their particles, which generates cracks, cracks, fissures and (or) cracks in the different elements that make up the structure of the house (walls, roofs, among others). The variability, instability and increase of these climatic effects mean that the current traditional dwellings occupied by the Weenhayek are not adapted to their environment, compromising their durability over time, so it is important to implement alternative solutions to rescue, preserve and improve the original construction characteristics and safeguard the habitat of the Weenhayek native people. adapting these homes to the new environmental reality of the territory they occupy in the province of Gran Chaco in Bolivia.

In this context, the proposal for the improvement of the traditional dwellings of the Weenhayek people in the Chaco, Bolivia, results from the reviewed literature, from the contemporary cultural, social and environmental situation (mentioned above), as well as from the perception of this population (based on the empirical technique applied) through the proposed modeling through four phases that were identified as a result of the theoretical-empirical consensus of scientific research. The model was achieved from a planned adaptation to droughts and floods, and managed to identify, characterize and propose four variables with their respective study parameters that are directly related to the implementation of a house and its construction process from the incidences of the referred climatic conditions on them that improve and conserve them. This model develops the integration, interaction and interconnection of cultural approaches (which identifies elements to be expressed in built spaces), constructive approaches (which focuses on housing in new methods of sustainability, among others), environmental approaches (for the conservation of natural resources in their entirety and the use of bioclimatic elements), territorial regulation approach (which allows security actions to be established for the stability and security of housing) and social education approaches (which induces learning among the main actors for the execution and sustainability of the construction process).

The proposed model presents enriched elements as a contribution to society, since it contributes to the strengthening of the evolutionary process of traditional Weenhayek housing, its conservation and promotion from the perspective of a planned adaptation that leads to a state of continuous resilience; and at the same time contemplates the planned adaptation based on the original construction tools in order to recover its social value and be a representative adapted to the current environmental climatic conditions. These, following a chain that correlates the life cycle of a construction, are projected as follows:

The first phase: location of the house is the first process, which has as its

beginning or fundamental input the evaluation of the conditions of the place where the house is located (location), within the limits of the Weenhayek indigenous territory in the province of Gran Chaco. This delimitation reflects the recognition by the national authorities of the right of this native people to the land they have inhabited over the years, where their culture and customs have developed.

This ancestral territory is part of the territorial study by the competent entities as a fundamental input to the planned adaptation process based on the geological, topographic and environmental conditions in general and to the dwellings specifically as a location area, which allows the necessary knowledge about the security of habitability for the construction of the dwelling, including, as appropriate, the conservation and proliferation of trees. The aforementioned studies include the physical-geological properties of the land, in order to guarantee the structural safety of the dwelling; the groundwater level and other properties that could be in favor or against the area to be occupied by a certain dwelling. On the other hand, these properties establish the evaluation of the necessity or not, of the use of other types of materials to improve the properties of the soil.

The topographic surveys that allow defining the risk conditions of the land, which leads to establishing the relationship between the floor level of the house, the level of the natural terrain and the relationship of the latter with the river in order to guarantee the safety of the conditions for the construction of the house. The topographic condition in case of not presenting favorable conditions establishes the conditioning of the land that involves technological solutions that must be supported by the Autonomous Municipal Government of Yacuiba (GAMY), which involves the elevation of the land, change of material, among others (**Figure 5**). This topographic conditioning of the terrain corresponds to the area occupied by the Weenhayek culture today in the province of Gran Chaco, who returned to their homes after the floods that occurred.

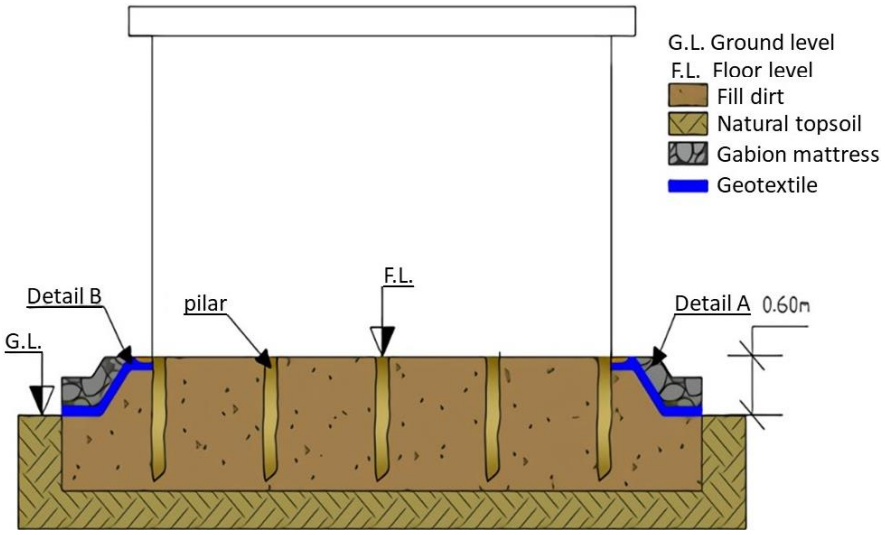

Figure 5. Flat topography with ground elevation.

Note: Own elaboration.

The possession of property according to municipal regulations and disposition of the house in relation to access roads and the river, standardized parameters from the

government entities that contribute to ensure the location of the houses. The location is conceived as another input for the evaluation of the physical space of the housing area where the determination of the area to be occupied and the dimension of the housing is contemplated according to normative parameters to ensure the minimum habitability conditions, a perspective that helps the quality of the inhabited space. As well as the orientation of the house to take advantage of the favorable natural environmental conditions such as lighting and ventilation, which allow a pleasant environment and guarantee the sustainability of the habitat (**Figure 6**).

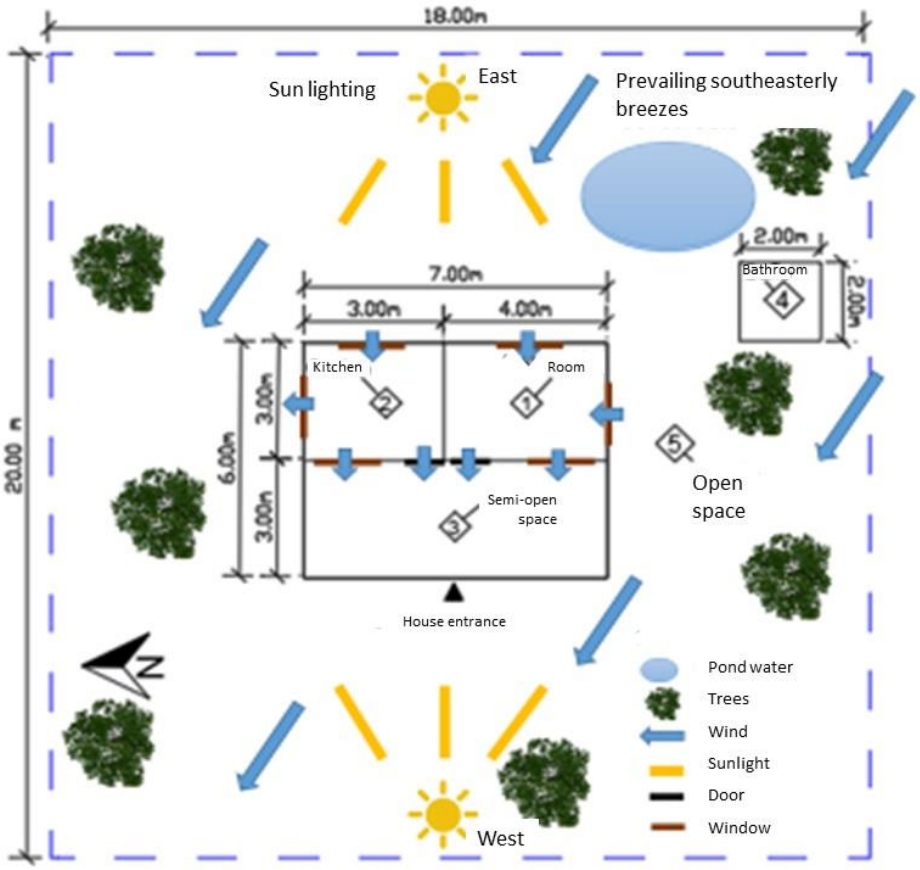

Figure 6. Location and spaces of the house with use of bioclimatic conditions.
Note: Own elaboration.

Also, a water pond is established that, together with the surrounding vegetation, generates a microclimate, and that together with the environmental conditions, fosters a more pleasant area for daily activities to be carried out in the province of Gran Chaco in Bolivia. The design phase of the house itself is conceived as a second process, which has as its input the quantity and dimensions of the component spaces of the house, which present dependency and connection with regulations established at the governmental level, in order to guarantee minimum conditions of habitability, and establish optimal situations of health, convenience and comfort.

This design preserves the cultural distribution of the original Weenhayek homes, which is characterized from a social point of view by the composition of the family, where the central couple slept in the nucleus and were in charge of feeding the fire on cold nights, while the offspring were arranged in a circle. In addition, it considers the

bioclimatic conditioning of the place due to the prevailing climatic conditions in the province (drought and floods), which allows establishing the location of the house and its spaces to take advantage of orientation and ventilation, as well as incorporating thermal insulators and eaves as a solution to the roofs of said houses, typical of contemporary times.

The construction materials phase is presented as the third process, where its physical properties of adaptability to extreme weather conditions are essential and make it participants in the planned adaptation. The foundation constitutes the first input of the analysis process because it is the one that supports the house. It uses traditional materials such as water, natural earth, highly hard wood (horcones), and new materials such as filler material stabilized with lime, linseed oil, and geotextile, which due to its physical properties protects the foundation from flooding and the action of heat, as it provides greater rigidity, stability, safety, and durability.

In the conformation of the walls, where protection against inclement weather (elevated temperatures, rainfall), stability and durability are adaptation parameters for which traditional materials are used such as water, hard and/or semi-hard wood, mud, grass or animal dung or leaves with thin branches cut from ancoche (Vallesia glabra), and new materials such as linseed oil, mud, caraguatá fiber fabric (Bromelia Hieronymi), geo mesh, metal clamps and nails, which stiffen and protect the walls, for insulation from high temperatures and together with the erosive action produced by rainfall and floods.

This is followed, as a process, by the covering with the use of traditional materials such as hard wood, mud, grass or animal dung or leaves with thin branches chopped from ancoche to stabilize the mud, water, caraguatá fiber fabric; materials obtained from the mount or forest that surrounds the Weenhayek. New materials such as linseed oil, fine plastic sheets, millimeter metal mesh, thermal insulators, zinc sheets, bolts, which as a whole give greater protection, stability, and resistance to the roof, and at the same time protect the other elements that make up the house, such as walls and foundations, against inclement weather (**Figure 7**).

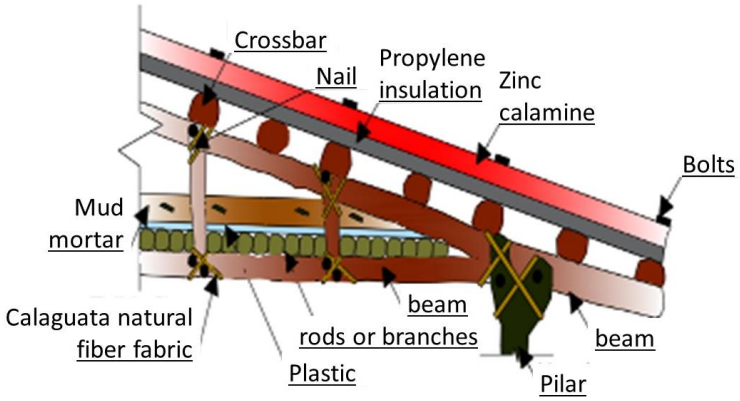

Figure 7. Use of traditional and non-traditional materials on the roof.
Note: Own elaboration.

It is followed by the floor, as another process, which is made up of traditional materials such as natural earth, cement and water, and stabilized with new material such as cement, which improves the resistance, rigidity, volumetric stability and

decreases the permeability of the soil. On the other hand, there are the materials used in the toilet areas, with the use of traditional materials such as highly hard wood, mud, grass (or) animal dung or chopped ancoche leaves, and water and caraguatá tissue. As well as new materials such as linseed oil, geogrids, nails, thermal insulation, zinc sheet metal, bolts, and sticky paints that stabilize, stiffen, and protect the component elements of these areas (foundations, walls, roofs).

The construction techniques phase is presented as the fourth and last process, within this model that seeks to rescue, improve and preserve original construction techniques that have emerged and remained in this province for decades since a planned adaptation. As an initial entry, the foundation is presented where the technique of burial of posts that is traditionally carried out, is reinforced by expanding the excavation site, adding stones together with compacted earth and wrapped by geotextiles around the entire perimeter, leaving said materials exposed on the floor level to connect with the walls as part of a system to be articulated. In this way, a greater compaction, stabilization, consistency and rigidity of the foundation is achieved, capable of absorbing greater impacts as a result of earth movements and resisting external forces (winds), which could compromise the structural stability of the house.

Another entry is the technique for the conformation of the walls, where the splashing of mud is used, which involves the placement of continuous wood one after the other between posts (walls). These woods will sink into the ground and will be fastened together with caraguatá fabric and with nail reinforcements where appropriate. At the base of these, geotextiles must be placed that will wrap the wood from the ground to the roof level. On the wood, mud mixed with grass or animal dung must be tarnished until reaching a thickness of rigid consistency on the outside and inside from the axis of the wood (**Figure 8**). Then proceed to adjust the geotextile up to the level of the roof.

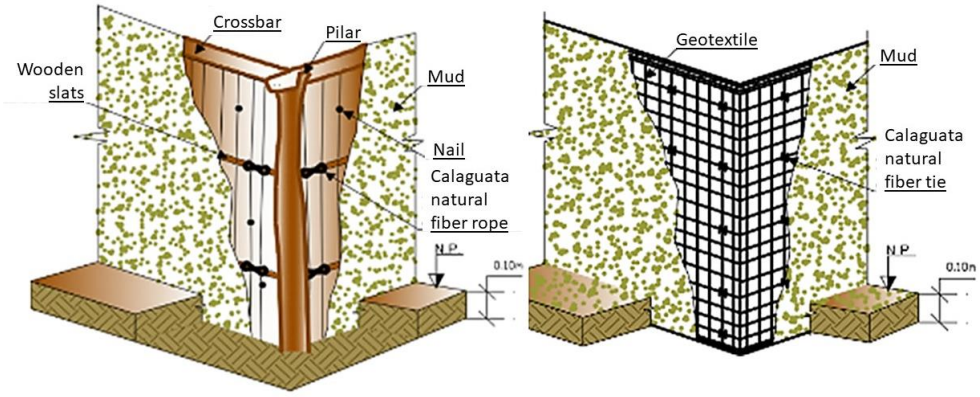

Figure 8. Laying mud on wood.

Note: Own elaboration.

It is clarified that the geotextiles must be superimposed one on top of the other and in the corners, and their attachment must be done towards the wall, strongly tied by caraguatá fabrics left before the walls were ripped between the high and long timbers placed. Once the mud has dried and the geotextile has been placed, mud prepared with grass, animal dung or branches and chopped leaves of ancoche is placed

on both sides of the wall, leaving a smooth surface. In this way, greater stability and integrity of the materials on the wall is achieved, since the geotextile will give greater support and increase the resistance of the wall (mud, grass, wood), thus avoiding dismemberment or cracking that could compromise the structural stability of the house. On the walls, it should be planned to leave the spaces for windows or doors by means of wood strongly attached with caraguatá fabric, following the same procedure as the walls.

On the other hand, the roof is executed with the improved mud cake technique where the stringers (trusses) must be placed on the beams and fastened with nails on the strips (beams). Above the crossbeams, rods or thin tree branches should be placed in a row without bark and tied with caraguatá fabric. After that, the plastic must be placed over the entire surface to avoid any leakage (**Figure 9**); Two layers of mud mixed with grass or animal dung or leaves and branches cut from ancoche are placed on top.

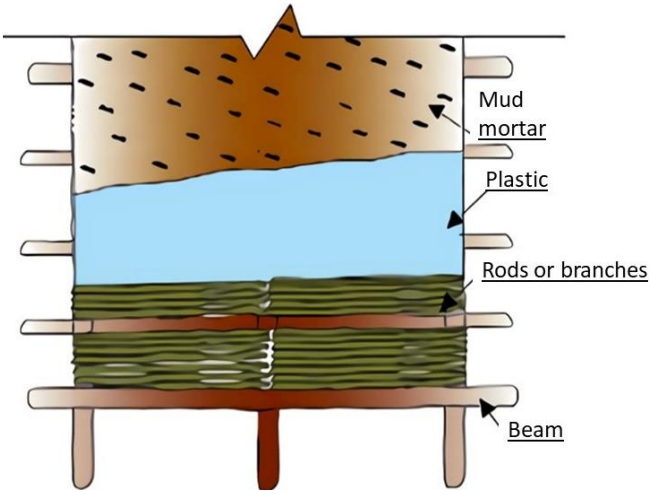

Figure 9. Mud mortar constructive composition (roof).

Note: Own elaboration.

Prior to the placement of the mud cake, a millimeter metal mesh must be placed in the perimeter area of the roof, it must surround the mud cake, together with the ventilation grills. Finally, the thermal insulation must be placed on top of the mud cake and the zinc corrugation attached to the beams with bolts. The roof must present an eave in all directions in order to protect the home. This technique provides: greater stability and rigidity of the mud cake in order to avoid its dismemberment or cracking, air circulation avoiding the accumulation of hot air, neutralizes a large proportion of the heat coming from the sun and takes advantage of natural lighting according to the time of year.

For the floor, the technique of soil stabilization with cement is used to improve the stability conditions of the interior surface of the house, for which the entire perimeter must be excavated, the earth removed, the mixture of earth, cement and water proceeded, and manual placement and compaction until a solid consistency is achieved. This technique provides greater resistance to the climatic events studied, giving a greater support capacity to the soil.

However, the establishment of the model has revealed a series of questions that

arise for the development of necessary lines of research as continuities expressed through academic implications and practical implications such as anthropological, ethnological and way of life studies of the Weenhayek in the study area. Among them, there are studies for the improvement, preservation and protection of traditional housing through the proposal of variants of the architectural model of the Weenhayek culture; studies to characterize the effects of climate change on the Weenhayek culture in other areas of knowledge such as social and economic, which also includes other groups originating from the Bolivian province of Gran Chaco such as the Guarani, Tobas, etc.; studies on educational programs on climate change, adaptation, and resilience to members of the Weenhayek culture; studies on programs to strengthen the rescue, conservation and maintenance of traditional Weenhayek dwellings; and application of the housing model to improve the Weenhayek culture in other native cultures of the province of Gran Chaco in Bolivia.

4. Conclusion

This section is not mandatory but can be added to the manuscript if the discussion is unusually long or complex.

The resilience of socio-natural systems to climate change is a planned adaptive capacity, which absorbs, resists and recovers for the preservation of these systems because it can help counteract and/or cope with the effects of climate variability determined by extreme natural climatic phenomena such as the one in the province of Gran Chaco, Bolivia. From this perspective, the model establishes the improvements of traditional dwellings, from a current trend of deterioration to one of preservation, conservation and growth in the Weenhayek culture, through the following elements:

- Rescues, conserves and improves the traditional Weenhayek house;
- Respects the cultural design of the house that integrates local patterns of the environment, ecosystem and contemporary construction elements without affecting its image, based on the materials and techniques used, depending on the location near the river and its stability as part of its ancestral territory;
- It applies bioclimatic elements such as lighting and natural ventilation that value current regulations and helps conservation and environmental promotion;
- The materials and construction techniques used are of a traditional nature, but with contemporary elements that improve their application, durability, stability, as an articulated construction system, and includes the social perception for the maintenance of the house;
- Commits governments in all instances to the technical-constructive study of the rural areas of the human settlements of the Weenhayek people;
- Establishes a starting point towards new studies focused on native peoples.

In another order, this model is a tacit contribution to the manual for construction of social housing of the Ministry of Public Works, Services and Housing of Bolivia (MOPSVB) (2020), as one of the parameters of adequate housing for the adjustment and expression of cultural identity. It also helps the Bolivian Guide to Construction of Buildings, Ministry of Public Works, Services and Housing of the Plurinational State of Bolivia (MOPSVEPB) (2015), which establishes basic housing typologies aimed at low-income sectors (of social interest); as well as the Bolivian Construction

Regulations, Vice Ministry of Housing and Urban Development of Bolivia (RBCVVUB) (2015), among other regulations issued by the Ministry of Economic Development and Ministry of Public Works of the Plurinational State of Bolivia. From this perspective, the model has made it possible to establish an alternative that enriches the houses from their durability, habitability conditions, preservation of original construction tools in order to recover their social value and be a representative adapted to the current climatic conditions of the region.

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