Chapter 31
Robustness of Residential Houses in Ecuador in the Face of Global Warming: Prototyping and Simulation Studies in the Amazon, Coastal and Andes Macroclimatic Regions

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Abstract Ecuador is a small country with high-frequency climatic variability. The principal macroclimatic regions are the Amazon rainforest, with a hot and humid climate; the tropical coast, also with a hot and humid climate; and the highlands, with a tropical mountain climate. The government is working on policies regarding the energy efficiency of all kinds of buildings. In 2011, the Ministry of Urban Development and Housing (MIDUVI), in a design competition called ‘Dwellings for Climate Change’, selected three residential house typologies, one for each macroclimatic emplacement in the country. The winner dwellings were designed considering passive architecture concepts; however, some simulation studies conducted by the National Institute of Energy Efficiency and Renewable Energy in 2014 showed that in many cases the new design proposals have poorer performance than the standard dwelling typically seen in Ecuador for all climatic emplacements. To validate the simulation results, new simulations were conducted using current weather data. The output searched was the total discomfort sensation instead of the thermal demand or energy consumption (heuristic). In addition, global warming was taken into account by simulating future situations in the A2 scenario proposed by the Intergovernmental Panel on Climate Change. Future climate was modelled using the Climate Change World Weather Files Generator developed by the Chartered Institution of Building Services Engineers. Results show that building design in Ecuador is influenced by standards that come from colder countries. This fact leads to generally poor result in terms of natural cooling performance, even in the actual climate. Global warming and urban development, especially in the coastal region, will increase cooling needs, so building design

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guidelines for Ecuador will have to be reconsidered and focus in particular on heat evacuation problems instead of heating demand reduction.

Keywords Global warming • Climate change mitigation and adaptation • Social housing • Ecuador

1 Introduction

Ecuador is starting to consider climate change as a priority for the country's development. Recently the Under Secretariat for Climate Change was founded, and many ministries have started to insert related topics in their political agendas. In particular, the Ministry of Urban Development and Housing (MIDUVI) launched in 2011 the competition 'Dwellings for Climate Change' in order to improve the basic residential dwellings that are still being built in all climates of the country. For instance, Ecuador, although it is small, has a unique climatic diversity: in the Andes the climate is tropical mountain, in the Amazon it is tropical wet and in the coastal region it is hot, both arid and humid, depending on the specific location. One of the competition goals was to show the need for different designs for each climate, even for residential dwellings, that must be very inexpensive. The National Institute of Energy Efficiency and Renewable Energy (known by its Spanish acronym INER) is also developing some prototypes for the different climates of Ecuador [1]. In this chapter, a simulation study is conducted to estimate the hours of discomfort (both undercooling and overheating) that residents may feel in the base case (the actual MIDUVI residential house) and in the three prototypes that won the competition. Simulations were conducted for the current climate (typical meteorological year, or TMY) and for the future (2050 and 2080) taking into account the effects of global warming under the Intergovernmental Panel for Climate Change (IPCC) A2 scenario. Since in Ecuador heating and air-conditioning systems are used by only a small part of the population (the wealthy), an analysis was conducted considering naturally ventilated buildings to try to determine the total hours of discomfort during the year.

2 Methodology

In this chapter IPCC data are used to simulate the future energy performance of three types of buildings. Future data (2050 and 2080) are obtained using the Climatic Change Weather Files Generator developed by Jentsch et al. [2] and TMYs are obtained from the meteorological service of Ecuador INHAMI [3]. The selected scenario to simulate the future is the IPCC's A2 scenario. This scenario describes a heterogeneous world, with slow population increases and differences among regions and social classes. The result is a medium-high emissions scenario (Fig. 31.1). A description of the climate of the considered cities, deemed representative of the macroclimates of Ecuador, is as follows:

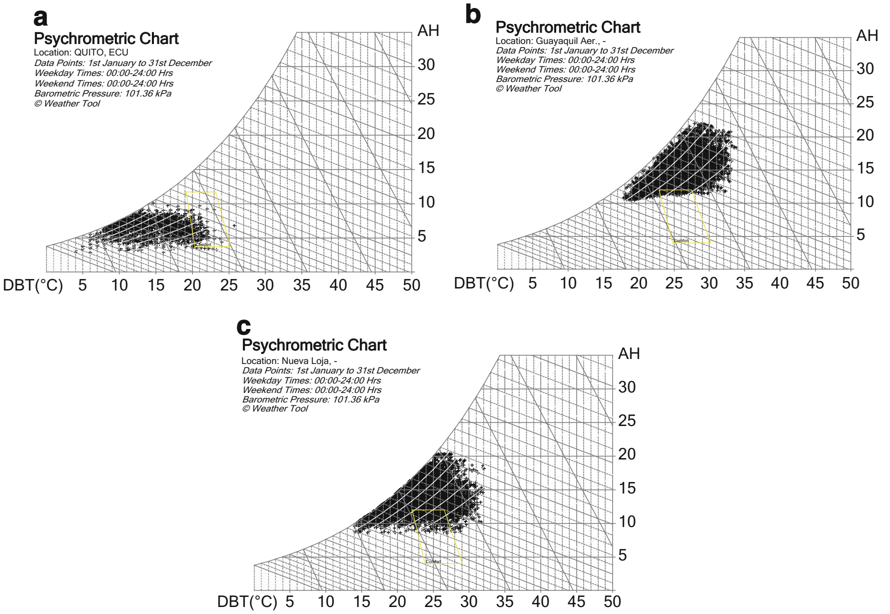

Fig. 31.1 Givoni chart for Quito (**a**), Guayaquil (**b**) and Nuevo Loja (**c**)

- The climate of Quito (0°14′S, 78°31′W longitude, 2850 m elevation) is tropical mountain, with mild diurnal temperatures and colder nights, in both wet and dry seasons. Radiation levels are high, the urban density increases the heat retention effect and a breeze is sometimes present.
- The climate of Guayaquil (2°11′S, 79°53′W, 4 m elevation) is hot and wet throughout the year. The ocean breeze, when present, is very important for the natural cooling of buildings. Urbanization affects the temperatures of the city, and in many cases, new constructions along the first costal line block the wind.
- The climate of Nueva Loja (0°5′5″N, 76°52′58″W, 297 m elevation) is tropical wet, with high humidity and temperatures throughout the year and a night–day oscillation slightly higher than in Guayaquil.

The building typologies analysed are described as follows:

- A MIDUVI house is a small family dwelling with external walls made of cement block having a thermal transmittance of 1.8 W/m^{2}K, a metal deck roof with a transmittance of 5.2 W/m^{2}K and 15 % transparency on the main façades (simple glass and aluminium, transmittance 5.1 W/m^{2}K).
- The house proposed for the Amazon is a family dwelling with external walls of reeds having a thermal transmittance of 4.5 W/m^{2}K, a roof made of polypropylene with a transmittance of 2.7 W/m^{2}K and 10 % glazed surface.
- The house proposed for the mountain region is a more compact house with walls of concrete (transmittance 1.8 W/m^{2}K), metal deck roof (transmittance 5.2 W/m^{2}K) and 20 % glazed surface.

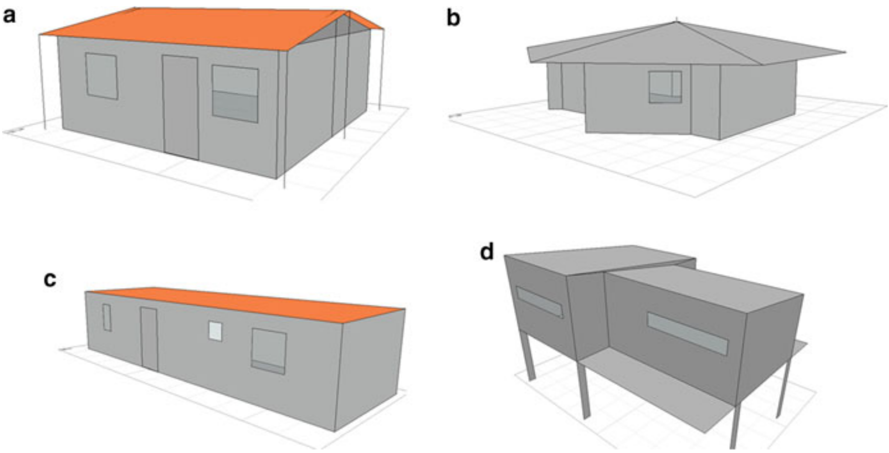

Fig. 31.2 House models for MIDUVI (**a**), Amazon (**b**), mountain (**c**) and coast (**d**)

Table 31.1 Transmittances and glaze percentage of building typologies

Building	U wall (W/m^{2}K)	U roof (W/m^{2}K)	Glazed surface (%)
Mountain	1.8	5.2	20
Amazon	4.5	2.7	10
Coast	3.5	5.2	10
MIDUVI	1.8	5.2	15

- The proposed coastal house is an elevated house with walls of light concrete (transmittance 3.5 W/m^{2}K), steel roof (transmittance 5.2 W/m^{2}K) and 10 % glazed surface.

All houses have the same occupancy density of 10 m^2/person for a 24 h period. Figure 31.2 shows the models for the dwellings, and Table 31.1 summarizes the material properties.

Simulations were done using Types 56a (multizone building) in the Trnsys tool (version 16). Climatic TMY files were read in Type 109, sky cloudiness was calculated using Type 69b and psychometric variables by Type 33e. The Jentsch method to generate TMY future data uses 'shift' and 'stretch' modifications for temperature, 'stretch' modification for wind speed and global radiation and 'shift' for relative humidity and atmospheric pressure. For more detailed information, see the tool manual [4]. The MIDUVI house was simulated in both main orientations north–south (N–S) and east–west (E–W), whilst the prototypes were simulated using the recommended orientations, N–S for the Guayaquil dwelling and E–W for the one in Quito. Recall that a 0 latitude means that E–W orientations guarantee a solar gain, whilst the N–S orientation has no solar gain throughout the year.

3 Results

Figure 31.3 shows the results in terms of discomfort hours for the MIDUVI house in both orientations and for the new prototypes. Table 31.2 summarizes the discomfort values.

These results confirm the possible impact of climate change on the built environment and the need for a new concept of thermal regulation for the country. Much research is currently being done on this topic for tropical, arid and Mediterranean climates; see for example the work of Palme et al. [5].

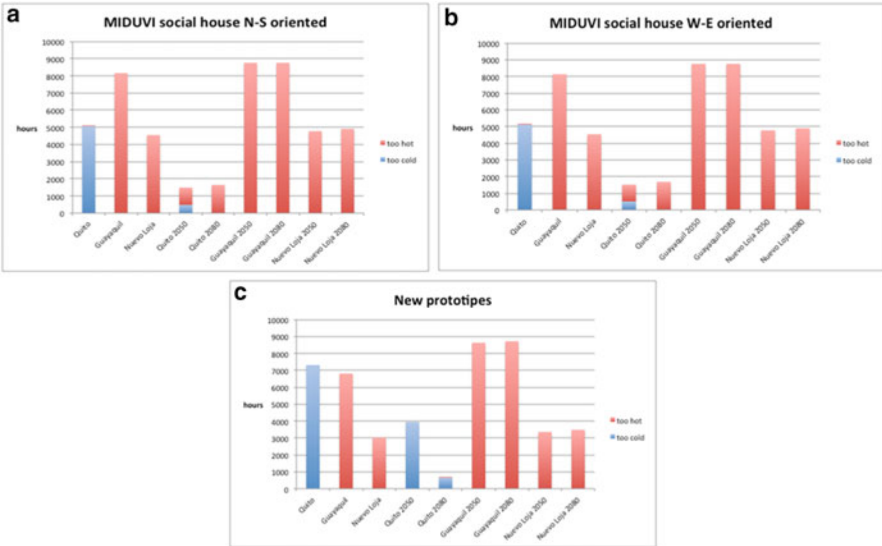

Fig. 31.3 Discomfort hours for MIDUVI house N–S (**a**), E–W oriented (**b**) and new prototypes (**c**)

Table 31.2 Discomfort hours in analysed cases

Case	MIDUVI house N–S		MIDUVI house E–W		New prototypes	
	Too hot (h)	Too cold (h)	Too hot (h)	Too cold (h)	Too hot (h)	Too cold (h)
Quito TMY	41	5071	29	5121	0	7315
Quito 2050	1000	487	1009	511	0	3939
Quito 2080	1640	9	1676	9	8	660
Guayaquil TMY	8161	0	8139	0	6810	0
Guayaquil 2050	8760	0	8760	0	8632	0
Guayaquil 2080	8760	0	8760	0	8724	0
Nuevo Loja TMY	4552	0	4536	0	3024	0
Nuevo Loja 2050	4780	0	4776	0	3352	5
Nuevo Loja 2080	4913	0	4898	0	3480	5

4 Conclusions

The present work showed that new designs for houses are needed in Ecuador. Climate change will affect the performance of buildings; for example in the highlands the MIDUVI house will undergo a shift from heating to cooling demands. In Guayaquil and Nueva Loja, overheating will be the problem and global warming will increase the effect. With respect to the new prototypes, it seems that the different design could reduce the bad performance of the MIDUVI house, but it will not be sufficient. Considering future scenarios, in both hot emplacements (Guayaquil and Nueva Loja), the overheating sensation will be very high. Only the new prototype for the highlands shows significantly better future performance (but not with the current climate) with respect to the MIDUVI house, avoiding overheating. The energy certification of dwellings, under development in Ecuador, will have to focus on heat evacuation in all climates, including the highlands. Going forward, a priority should be to use more simplified calculation methods to estimate the potential to cool buildings naturally. At the urban district level, environmental studies to quantify the contribution of buildings to the heat island effect and its dependence on the urban form are also needed, as in other climates [6]. The blockage of natural breezes in the case of Guayaquil is also a very important topic and should be studied and discussed as soon as possible.

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References

1. Lobato A, Vaca D, Rivela B (2014) Coupling multi-criteria analysis and life cycle approach for sustainability assessment of social housing in Ecuador. In: Proceedings of the BauSim 2014, Aachen
2. Jentsch MF, Bahaj AS, James PAB (2008) Climate change future proofing of buildings—generation and assessment of building simulation weather files. Energy Build 40 (12):2148–2168
3. IPCC Special Report (2000) Emissions scenario. IPCC official site http://www.ipcc.ch
4. Climatic change weather file generator manual (2009) UKCIP official site http://www.ukcip.org.uk or Southampton School of Civil Engineering and the Environment official site http://www.serg.soton.ac.uk
5. Palme M, Isalgué A, Coch H (2013) Avoiding the possible impact of climate change on the built environment: the importance of the buildings' energy robustness. Buildings 3(1):191–204
6. Palme M, Guerra J (2014) A critical assessment and projection of urban vertical growth in Antofagasta, Chile. Sustainability 5(7):2840–2855