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Performance-based validation of climatic zoning for building energy efficiency applications

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HIGHLIGHTS

- A procedure to support the validation of climatic zoning is proposed and demonstrated.
- The procedure is based on building energy simulations of representative archetypes.
- Simulation results are used to calculate a climatic zoning quality index.
- The new index quantifies the agreement between climatic zones and building performance.

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ABSTRACT

Climatic zoning for building energy efficiency applications is an important element in building energy policy and regulations. There are several methodologies available to conduct climatic zoning, providing significantly different results. Currently, there are no procedures to assess the validity of a proposed climatic zoning, hindering the decision to use one particular climatic zoning methodology instead of another. This paper introduces a quality index and a procedure to support the validation of climatic zoning. The procedure is based on building performance simulation results concerning the building stock that is targeted in the climatic zoning policy or program. Simulation results are used to calculate a new index, the Mean Percentage of Misclassified Areas (MPMA), which assesses the quality of the zoning under analysis. The capabilities of this procedure were demonstrated by the evaluation of four alternatives for the climatic zoning of Nicaragua, obtained using different methodologies and previously reported in the literature. The building stock used in this case study is composed of a few archetypes based on typical naturally ventilated dwellings in this country. Simulations were conducted using the program EnergyPlus for a total of 328 locations in Nicaragua. Degree-hours of discomfort based on the adaptive model of ASHRAE Standard 55 were used as a performance indicator. Results indicate that zoning obtained using cluster analysis and cooling degree-days may misclassify 1 out of 5 areas in Nicaragua (MPMA around 18–20%). This study concludes that the validation procedure and proposed index are useful for highlighting qualities and deficiencies of existing climatic zoning methods, particularly when these methods are used in less conventional applications, such as for policy making targeting naturally ventilated dwellings in tropical climates. The application of this procedure in more than 50 countries which adopt climatic zoning is foreseen as the next step in his area, substantially affecting the prescription of building materials and components worldwide.

1. Introduction

Climatic zoning is an important tool in building energy policy and regulations [1–3]. This tool has been implemented in at least 54 countries which are responsible for more than 85% of world primary energy consumption [4]. There are several approaches available to conduct climatic zoning [5–7] and choosing the most suitable methodology for a given country has proven to be a hard task [4]. This difficulty has important implications in the global energy policy scenario [8–10] as many labelling programs [11], standards [12,13] and regulations [14] rely on such methodologies. In the tropical context, energy conservation strategies derived from climatic zoning will have a

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substantial impact on the future of global energy use, as the population and energy demand grows faster in this region than anywhere else in the world [15–17].

The complexity of the proper selection of climatic zoning methodologies has been demonstrated in various studies [1,7,18]. A recent comparison of three widely used methodologies for climatic zoning (degree-days, cluster analysis and administrative divisions), carried out for Nicaragua, a tropical country in Central America [7], could not identify the most adequate methodology for the zoning of this country. A qualitative analysis showed that all methodologies have particular strengths and deficiencies [7]. In quantitative terms, this recent comparison could not offer any indication of the correctness of the zoning generated from each methodology, but the study made an attempt to quantify the level of agreement of results obtained using different methodologies. Results indicate that methodologies agree on the classification of 63% of the territory analysed, while the remaining 37% were placed in different zones depending on the methodology applied [7]. These results, along with an extensive literature review of climatic zoning methodologies [4], highlight the need for a procedure to assess in quantitative terms the validity of climatic zoning for building energy efficiency applications, supporting the choice for a particular climatic zoning methodology.

A variety of climatic zoning methodologies have been used for many years in several fields (e.g. predict thermal expectations of tourists [19], areas suitable for crops [20,21], wind power [22]). The variety of applications of climatic zoning implies that a given set of climatic zones must be validated for a specific purpose, as zones that may suit well one application (e.g. agriculture) may have major deficiencies if applied to another purpose. To the best of the authors' knowledge, in the field of climatic zoning for building energy efficiency applications, no attempt to conduct a systematic validation has been reported in literature to date. Climatic zoning results are usually assumed to be correct and valid per se, being directly applied to building energy regulations (as schematically represented in Fig. 1a). The approach in Fig. 1a is based on a weather centred definition where climatic zones are:

> *"regions which exhibit similar meteorological conditions for the main weather parameters which affect the heating and cooling energy requirements of buildings."* [23]

The definition above concentrates the entire analysis on the climate itself. The actual heating and cooling energy requirements of buildings are seldom analysed to define climatic zones. Climatic zoning methodologies using this approach are based on expected levels of similarity in climate variables within the zone, adopting particular statistical tools and assumptions in their analysis. Each methodology adopts a variety of assumptions (often based on clear and valid reasoning), being impossible to favour one methodology over another. As analyses only address climatic variables, there is no attempt to characterize, in terms of performance, the complex interaction between climate and building stock over the course of the year. With no information on performance, it is impossible to take an informed decision on the validity of assumptions adopted by each climatic zoning methodology. Therefore, the weather centred definition is not particularly suitable if one intends to validate the climatic zoning, inquiring on the match between climate and building performance variations throughout the territory.

An alternative scenario to the climate-centred definition is shown in Fig. 1b, where validation of climatic zoning precedes its application in building energy regulations. This scenario is based on a building performance centred definition, which is also valid for prescriptive-based approaches. In this scenario, climatic zones are:

> *regions in which a set of performance indicators regarding relevant buildings show (1) significant variation between identical buildings located in distinct zones and (2) small variation between identical buildings located at different points within the same zone, resulting from variations in climatic conditions.*

This definition facilitates the evaluation of assumptions adopted by each climatic zoning methodology, as the effect of these assumptions on the energy performance of a relevant set of buildings is the key element of this approach. If the assumptions are adequate, identical buildings in different zones will have very clear and distinct performance and identical buildings within the same zone will have similar performance (complying with the definition above). Under this definition, climatic zoning can still be carried out with no performance data, e.g. using the degree-days methodology. However, the validity of the resulting climatic zoning can only be demonstrated if performance data is available for all relevant points in each zone, considering a set of relevant buildings (the production of performance data using simulation is discussed in detail in this paper). Based on these building performance data, policymakers can evaluate if the magnitude of variations within and among zones is acceptable (or not), closing the cycle in Fig. 1b. The paper proposes a metric to facilitate this decision-making process.

The present study heavily relies on two previous research studies Refs. [4,7]. Ref. [4] is a review paper that compares the features addressed by various methods for climatic zoning. By doing so, it exposes the large range of options available for climatic zoning, and the

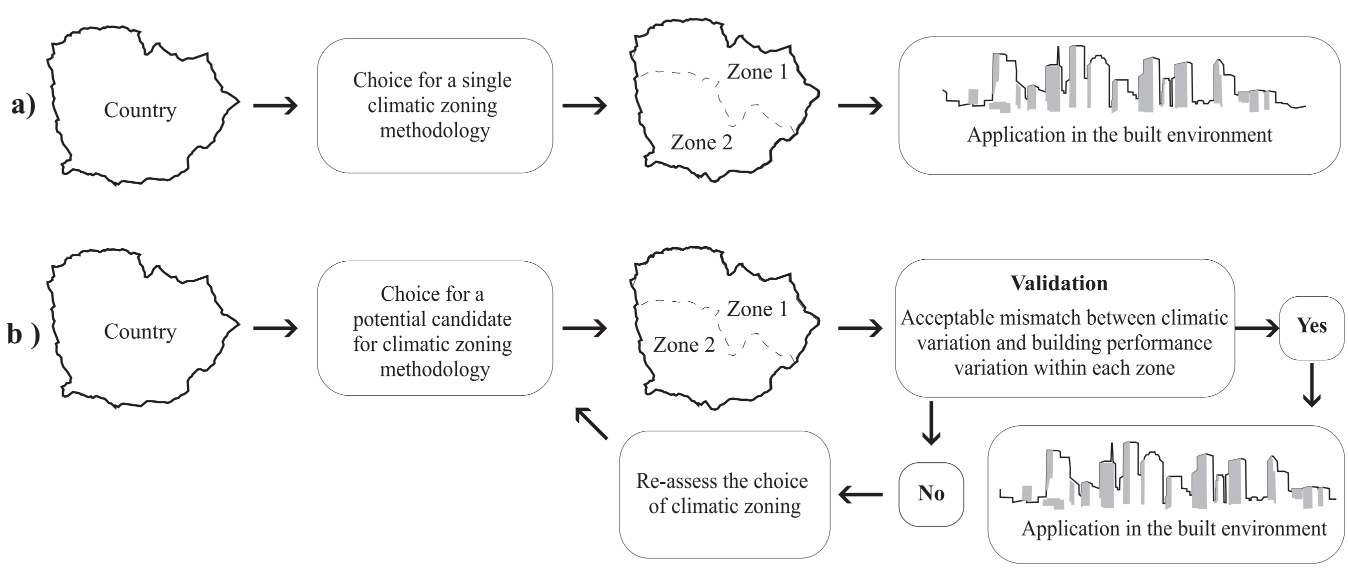

Fig. 1. Climatic zoning methodological flow (a) current approach and (b) proposed approach.