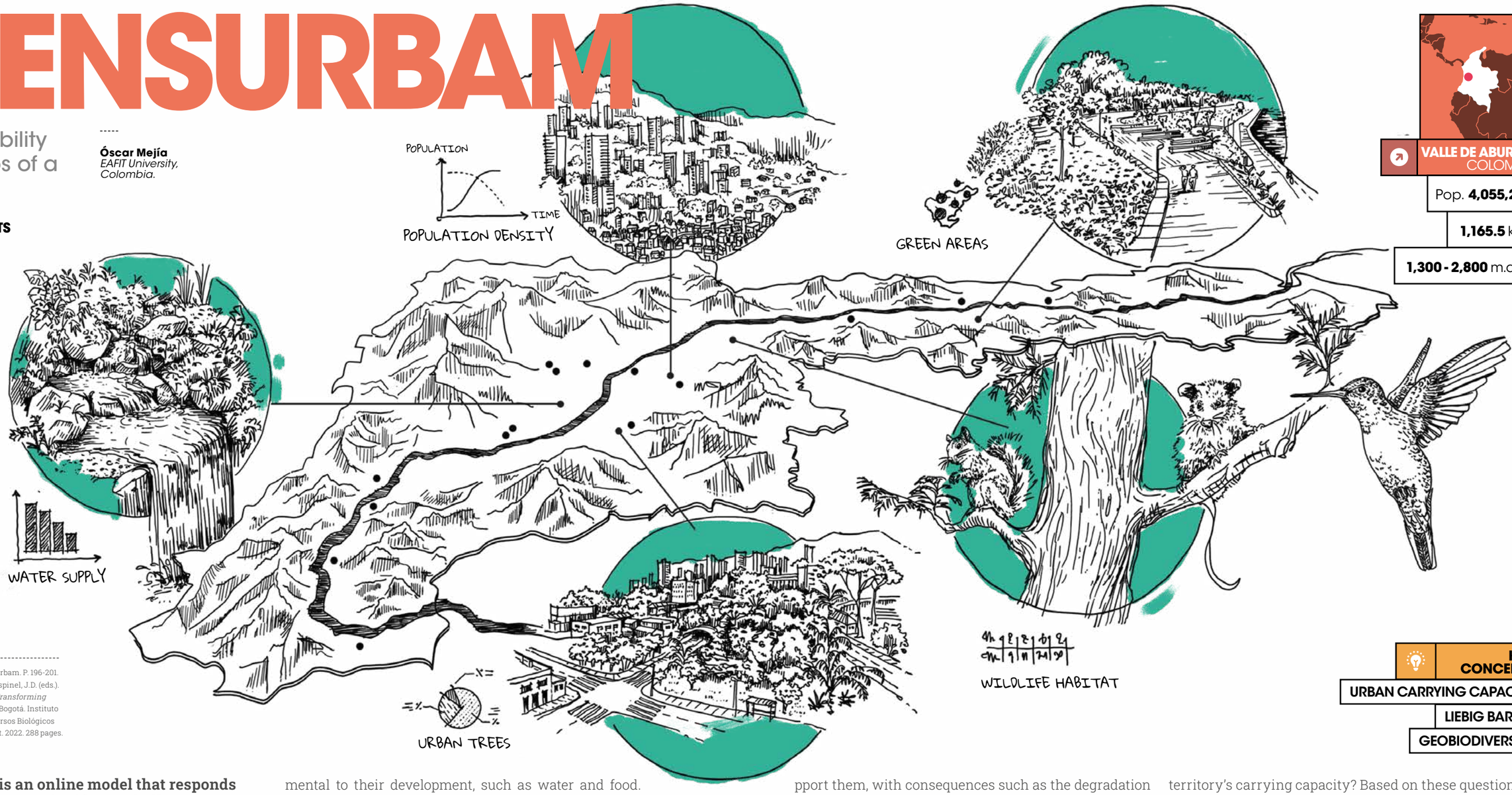
DENSURBAM

Sustainability scenarios of a territory

Óscar Mejía
EAFIT University, Colombia.

COMMITMENTS
1 6 8



VALLE DE ABURRÁ, COLOMBIA

Pop. **4,055,296**

1,165.5 km²

1,300 - 2,800 m.a.s.l.

KEY CONCEPTS

URBAN CARRYING CAPACITY

LIEBIG BARREL

GEOBIODIVERSITY

Quote as: Mejia, O. Densurbam. P. 196-201. In: Mejia, M. A., Amaya-Espinel, J.D. (eds.). *BiodiverCities by 2030: Transforming Cities with Biodiversity.* Bogotá. Instituto de Investigación de Recursos Biológicos Alexander von Humboldt. 2022. 288 pages.

Densurbam is an online model that responds to one of the most significant challenges facing cities and metropolitan areas: how to define the urban carrying capacity of a territory to ensure its ecological, social, and economic sustainability.

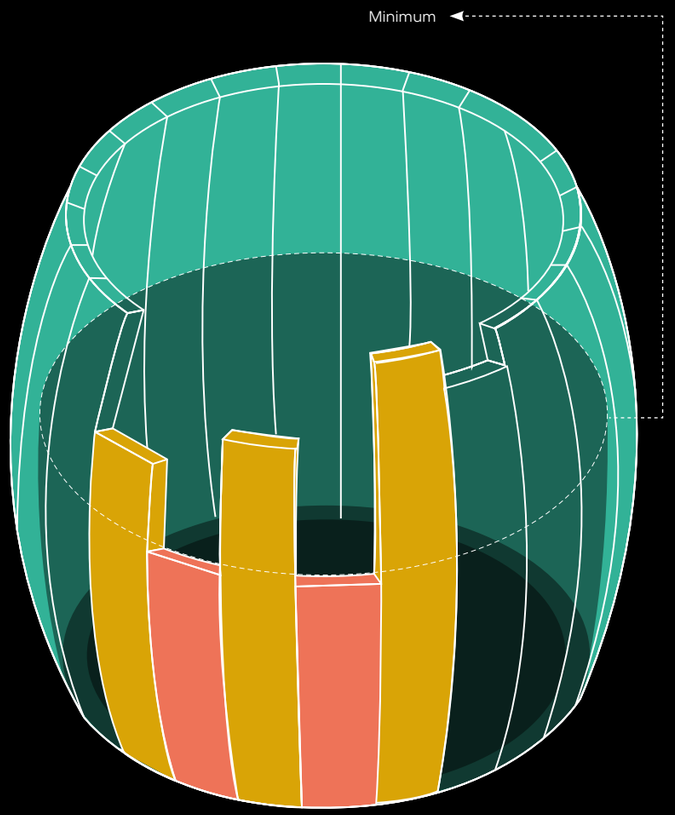
The accelerated urbanization process on a global scale has been possible thanks to cities overcoming their restrictions on access to natural resources that are fundamental to their development, such as water and food. However, this phenomenon, explained by growing industrial production and global trade, has led urban life to become disconnected from the true origin of these resources and a supply that is not infinite.

This dilemma is faced by metropolitan areas such as the *Valle de Aburrá*, a territory located in the central zone of Colombia's Andes Mountain range. This region's accelerated growth of Urban settlements has led to the loss and fragmentation of the ecosystems that support them, with consequences such as the degradation of soils suitable for food production and the urbanization of 56% of the water recharge zone.

Given this demographic expansion in the Valle de Aburrá, the Center for Urban and Environmental Studies (Urbam) of the Eafit University asked two questions: do the municipalities recognize this phenomenon's impact on their territory and the regional environmental system that supports them? And can the effect of joint and coordinated planning increase the territory's carrying capacity? Based on these questions, he designed Densurbam[1] : a mathematical model of anticipation that allows to simulate multiple futures in an agile way and to define sustainable growth scenarios[2] . The tool understands the territory based on units of analysis, such as regions, cities, neighborhoods, or villages, and works through a flexible, open-data IT platform. Thus, planners, and citizens in general, have a mechanism to establish the limits of sustainable growth of a city or region (Universidad Eafit, n.d.).

LIEBIG'S LAW OF THE MINIMUM AND BARREL ANALOGY

Sustainable · On the threshold · Unsustainable



Source:
Urbam EAFIT (2018) based on Liebig (1840).

$$SRI_{i,t} = \frac{\text{What is needed and to what extent?}}{\text{What is available and to what extent?}}$$

- **<1** the required capacity exists
- **1** on the threshold
- **>1** urban carrying capacity need to be improved

SRI: Support Ratio Index **i:** variable of analysis **t:** evaluation time

VARIABLES OF THE DENSURBAM MODEL ARE GROUPED IN THREE CATEGORIES

Ecosystems' health and resilience

- Air
  - Dilution of air pollutants
    - Emissions MP 2.5
    - CO2 (fixed and mobile sources)
- Water
  - Wastewater dilution
    - Dissolved oxygen
    - *BOD*
    - Coliforms
  - Evacuation of flows
    - Rain-runoff
    - Production of household liquid discharges
- Land
  - Recharging zones
    - Underground aglas
- Forest system
  - CO_2 fixing
    - CO2 fixation rate
  - Erosion prevention
    - *SST*
  - Wildlife shelter
    - Conservation of rural and urban forest cover

Resource availability

- Water
  - Water offer
    - Drinking water
- Land
  - Land offer
    - Land for shelter
    - Agricultural land
    - Supply of construction materials

Social skills for development

- Technology
  - Mobility
    - Spatial demand for mobility per inhabitant
    - Modal distribution
- Infrastructure
  - Public services
    - Water consumption
    - Energy consumption
    - Gas consumption
    - Production of liquid discharges
  - Public space and facilities
    - Effective public space per inhabitant
    - Proximity to effective public space
    - Facilities per inhabitant
- Culture
  - Densities
    - Inhabitants per hectare and dwellings per hectare
  - Use of solid waste
    - Excavation earth generation
    - Generation of construction and demolition waste
    - Recovered materials
    - Solid waste composting
  - Institutional
    - Tax performance

GROWTH LIMITS AND SUPPORT CAPABILITIES

Specifically, Densurbam defines 54 variables grouped into the following three categories (or parameters): the supply of resources, the health and resilience of the ecosystems that provide them, and the cultural behaviors of society that describe how it uses them. The model was built from quantitative data and causally connected multidisciplinary indicators, which explain the implications of planning on the sustainability of the territory and its carrying capacity.

To recognize the factors limiting the bearing capacity, Densurbam uses the **Liebig barrel** concept. Thus, the support ratio index (SRI), i.e., the ratio between resource supply and demand, is obtained by considering all the variables that make up the barrel, i.e., the area to be analyzed. After this evaluation, the model gets an indicator that specifies whether the region has the capacities it requires for its operation, whether it is on the threshold of sustainability or whether it needs to improve its capacities because its current or future situation is unsustainable.

BIODIVERSITY AS A CRITICAL FACTOR

The scenarios that Densurbam proposes for the territory's carrying capacity in the face of phenomena such as the loss of natural cover and climate change point to the importance of **geobiodiversity** and biodiversity in the current and future sustainability of the territory. For example, the model makes it possible to analyze the relationship between aquifer recharge zone areas and the minimum recharge zone areas of green spaces where rainwater infiltration occurs. This shows that the most significant urban center, Medellín, has significantly reduced the possibility of using groundwater as an essential resource and increasing its susceptibility to flooding and other phenomena associated with the alteration of its water dynamics. The model has also identified the reduction of natural land cover throughout the Valle de Aburrá and its effect on landscape fragmentation and connectivity.

Other analyses in this model show the direct relationship of urban growth with land use dynamics and the application of specific planning instruments. This shows, for example, that the vegetation cover of the territory was dramatically reduced with the approval of a land-use plan, even though it recognized a main ecological structure as a determinant of land-use planning.
An additional example is offered by Envigado, where this tool was applied in 2017 to propose two scenarios: a trend scenario and a desired scenario for 2030. Among the main challenges to achieve the desired future, or in other words, to live better, are the replacement and planting of trees, the improvement of infrastructure for wastewater discharge, and the increase of retirement spaces for the elderly, among others (Amaya, 2018).

ANALYSIS OF EFFECTIVE PUBLIC SPACE SUPPLY IN RELATION TO POPULATION GROWTH IN THE VALLE DE ABURRÁ

Variable of analysis: **Effective Public Space (m² / inhab)**
Unit of analysis: **Valle de Aburrá**
Population: **3,893,684**
Population density in 2017 (number of people / residential unit): **3.11**
Value of reference: **10.00**
Uncertainty Coefficient: **0.005**
Factor of Security for Sustainability: **0.025**

In this case, the Densurbam analyzes the supply of Effective Public Space (EPE in Spanish) by taking the 10 m² per inhabitant recommended by the United Nations and adopted in various urban policy instruments in Colombia as a reference indicator. According to Colombian regulations, EPE includes permanent public space made up of green areas, parks, and squares. Green public spaces play a key role in maintaining biodiversity, servicing ecosystems, and mitigating effects derived from climate change (Breuste et al., 2013).

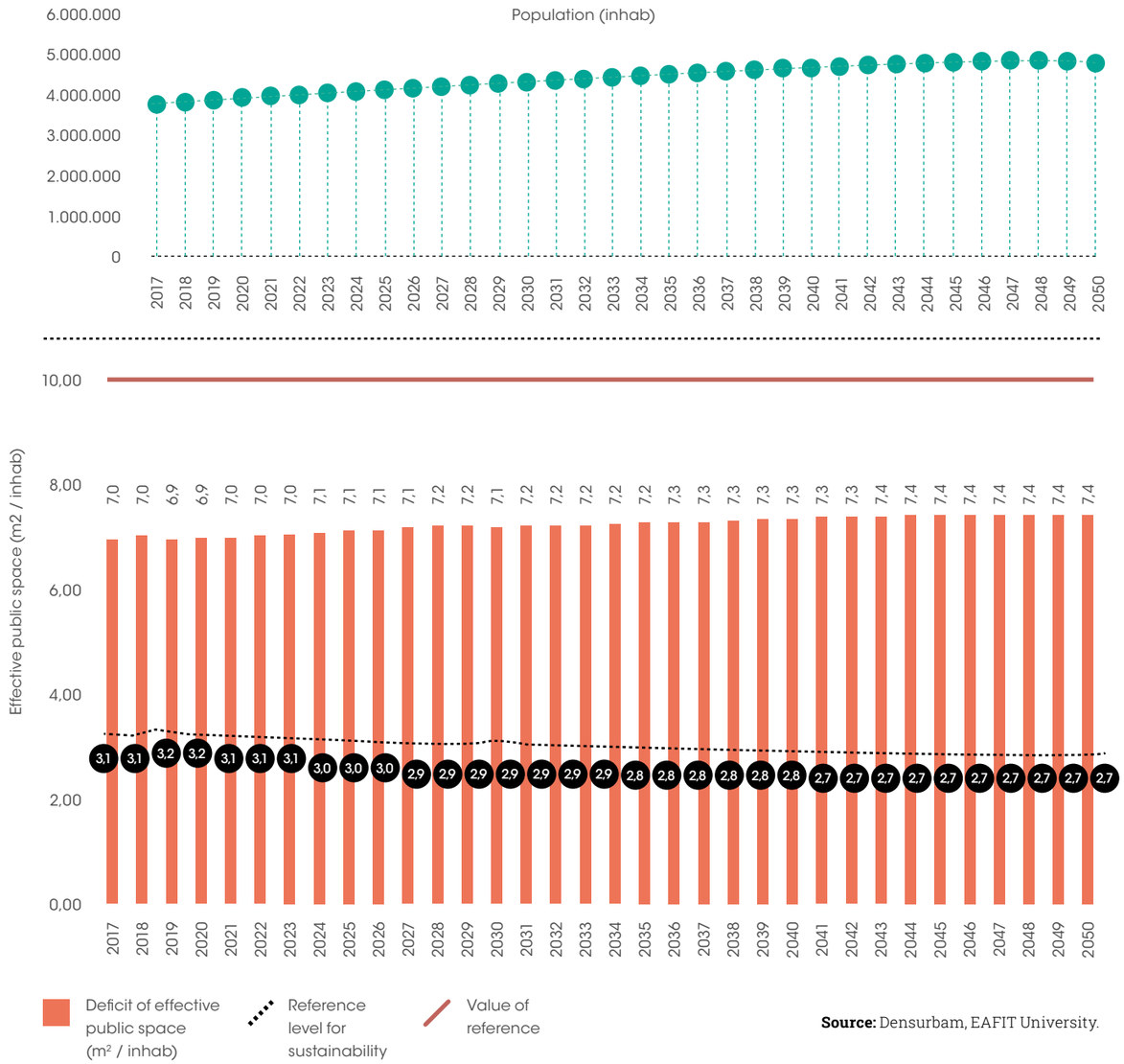
Here, Densurbam is modeling the relationship between population growth and the behavior of the EPE from 2017 to 2050, even taking into account the development of regional public space projects such as Parques del Río and Parque de Los Meandros. Thanks to this analysis, it is possible to identify a deficit in EPE of 69%. Likewise, according to population growth trends and ongoing regional projects, it is expected to reach 71% by 2030.

KEY LESSONS

Densurbam is a fundamental tool to orient and raise awareness: on the one hand, within the decision-makers on the implications of the various development plans on the carrying capacity limits of the territory; and on the other, within citizens on the close links between their demands for well-being and the capacity of the territory, ecosystems, and biodiversity to respond to them.

The model represents an important innovation that can change how the planning of territories under urbanization processes is carried out. In this sense, it is a planning tool. For example, Densurbam addresses human land occupation densities based on how many people can occupy the space according to their demand for human and natural resources and the territory's capacity to provide them, as opposed to the standard calculation of the number of dwellings or buildings per hectare.

Another critical aspect of the model is the explicit incorporation of aspects directly linked to biodiversity. In the case of the Valle de Aburrá, this is evident in the importance of the main ecological structure and the coverage of urban green areas in the support capacity of the territory due to their role as aquifer recharge and infiltration soils.



Source: Densurbam, EAFIT University.