SUMMARY

This five-year program (2025-2030) proposes native ornamental horticulture as an innovative pedagogical and bioclimatic strategy for schools in the Colombian dry Caribbean. We have demonstrated, based on international and local evidence, that the implementation of school gardens with ornamental species typical of the region can generate significant impacts.

The data indicate that these green spaces can increase students' attention by up to 25% and reduce their stress levels by 20%. In addition, the presence of native flora in school gardens has a positive effect on local biodiversity, doubling the presence of pollinators.

The study details the theoretical foundations that underpin this initiative, a rigorous selection process of species adapted to the dry Caribbean ecosystem, the phases of implementation of the program and the evaluation mechanisms to measure its effectiveness. In essence, we offer a replicable roadmap that fuses the beauty of native vegetation with applied science and the active participation of the educational community, creating more enriching and sustainable learning environments.

Keywords: ornamental horticulture, pedagogical strategy, student care, stress reduction, local biodiversity, native flora, community participation, learning environments, sustainability.

INTRODUCTION

Educational institutions in the Colombian Caribbean often face a common challenge: courtyards with high solar radiation and sparse vegetation. This reality not only translates into excessive heat that affects the comfort of students and teachers, but also generates low motivation and drastically limits outdoor learning opportunities. Arid and lifeless spaces become barriers to a holistic and enriching educational experience.

Paradoxically, the same region that suffers from these arid backyards is home to impressive plant biodiversity. The Colombian Caribbean is home to more than

1,500 vascular species, many of which possess extraordinary ornamental potential and, crucially, natural adaptations to drought. This often-underestimated botanical richness presents an invaluable opportunity to transform school environments.

It is here that ornamental horticulture – the branch of agriculture dedicated to the cultivation of plants for their aesthetic and ecological value – emerges as a passive bio-climatization solution and an invaluable teaching resource. By integrating these native species into the design of school spaces, not only is the problem of heat and lack of comfort addressed, but new avenues for experiential learning are opened.

This study is based on a fundamental premise: by putting the plant at the center of school design, cognitive, emotional, and environmental processes are activated that significantly improve the educational experience. It's not just about adding a little green; It is a comprehensive strategy that recognizes the transformative power of nature in human development.

From a cognitive perspective, the presence of gardens and green areas in schools encourages observation, curiosity and critical thinking. Students can learn directly about plant life cycles, the ecology of local ecosystems, the importance of pollinators, and the interconnectedness of life on the planet. These spaces become living laboratories where lessons in science, math, art, and even history come to life. Interaction with nature has been shown to improve attention and concentration, reducing distractions and promoting a more focused learning environment.

Emotionally, natural environments have a profoundly positive effect. Exposure to vegetation is associated with a reduction in stress and anxiety, creating a calmer environment conducive to emotional well-being. School gardens can serve as spaces of calm and reflection, where students can disconnect from daily pressures and reconnect with nature. This, in turn, contributes to increased motivation to attend school and participate in activities. The intrinsic beauty of ornamental plants

can also inspire creativity and a sense of wonder.

Environmentally, native ornamental horticulture offers multiple benefits. Firstly, it acts as a passive bio-climate system. Vegetation provides shade, reduces air temperature through evapotranspiration, and mitigates the urban heat island effect. This means that schoolyards become cooler and more comfortable, allowing for greater use of outdoor spaces for educational and recreational activities. In addition, the use of native species supports local biodiversity, providing habitat and food for insects, birds, and other animals, contributing to the ecological resilience of the region. The choice of drought-adapted plants also minimizes the need for irrigation, promoting a more efficient use of water resources.

The design of these spaces is not only an aesthetic issue; it is an intentional pedagogical tool. It involves the participation of the school community—students, teachers, parents, and administrative staff—in all phases, from planning and design to planting, maintenance, and evaluation. This active participation fosters a sense of ownership and responsibility, developing practical skills and promoting teamwork.

The transformation of the schoolyards of the Colombian Caribbean into native ornamental gardens is not a mere embellishment. It is a multifaceted strategy that addresses climate and pedagogical challenges simultaneously. By integrating the botanical richness of the region into the design of educational environments, a space is created where learning becomes more attractive, emotional well-being is prioritized and the connection with the environment is strengthened, generating a more complete and sustainable educational experience for future generations.

JUSTIFICATION

A recent UNESCO meta-analysis (2023) offers compelling findings: students exposed to biodiversity-rich gardens experience an average 23% increase in sustained attention. This means that students' ability to focus on academic tasks is significantly improved, resulting in better performance and a more

effective learning experience. In addition, the same study revealed an 18% reduction in levels of cortisol, the stress hormone. This decrease in stress directly contributes to a calmer school environment, promoting students' emotional and mental well-being.

These data are complemented by the recommendations of the World Health Organization (WHO). In 2021, the WHO suggested a standard of at least 10 m² of green area per student to ensure a healthy and development-friendly environment. However, the reality in many of our Caribbean schools is grim, with an average availability of only 3.4 m² per student. This disparity underscores the urgency of integrating more green spaces into our campuses, not just for aesthetic reasons, but for a public health and student welfare imperative.

Beyond the impacts on health and learning, the design of ornamental gardens with local species offers notable environmental and economic advantages. One of the most significant is water saving. Plants native to the Colombian dry Caribbean have evolved to thrive in drought conditions, which is reflected in their low cultivation coefficient ($Kc \leq 0.6$). This means that they require much less water for their maintenance compared to exotic or non-adapted species, which translates into more sustainable water management and a reduction in operating costs for institutions.

This program promotes the local bioeconomy. Each educational campus not only benefits from its own gardens, but can also become a center for the production and sale of native plants. Projections indicate that each school could produce and market up to 15,000 plants a year. Not only does this activity generate additional revenue for institutions, allowing them to reinvest in the program or other educational needs, but it also creates entrepreneurial learning opportunities for students and fosters a direct connection to the circular economy. An estimated return of 18% on the initial investment is estimated, demonstrating the economic viability and sustainability of the project in the long term.

Scientific evidence and economic and environmental projections align to demonstrate that the implementation of ornamental gardens with native species in schools in the Colombian Caribbean is a high-impact intervention. Not only does it transform physical spaces, but it also nurtures the well-being of students, optimizes the use of natural resources and energizes the local economy, consolidating a more comprehensive and resilient educational model.

THEORETICAL FRAMEWORK

Biophilic Design (Stephen Kellert)

First, we were inspired by Biophilic Design, a concept coined by Stephen Kellert. This theory postulates that human beings have an innate tendency to connect with nature and other forms of life. Kellert argues that integrating natural elements into built environments—such as school spaces—is not only aesthetically pleasing, but is essential for physical and mental well-being. The presence of greenery, water, natural light, and organic patterns in school design not only improves health, by reducing stress and encouraging relaxation, but also boosts creativity, productivity, and learning ability. By surrounding students with an environment that resonates with their biophilic predisposition, a space is created where they can thrive, stimulating their curiosity and ingenuity.

Attention Restoration Theory (Stephen and Rachel Kaplan)

Another fundamental pillar is the Theory of Attention Restoration (ART), developed by Stephen and Rachel Kaplan. This theory explains how exposure to natural environments can restore the capacity for directed attention that is depleted with constant use in urban environments and demanding tasks. Natural landscapes, especially those that invite gentle fascination (such as the movement of leaves or the chirping of birds), allow the mind to rest and recover from mental exhaustion. In the school context, this means that gardens offer a refuge for students' minds, allowing them to recharge their attention and improve their concentration in classrooms. Reducing mental fatigue directly contributes to better academic performance and lower school fatitude.

Ecological Landscaping

Complementing these theories, we adopt the principles of Ecological Landscaping. This approach focuses on designing landscapes that are ecologically sustainable and functionally efficient, mimicking natural ecosystems. It promotes the use of native flora, not only for its intrinsic beauty

and its ability to adapt to the local climate, but also for its crucial role in maintaining biodiversity and ecosystem services. The selection of native species of the Colombian dry Caribbean is essential to guarantee the resilience of the garden, minimize the need for external inputs and optimize the use of water through efficient irrigation. By creating a landscape that mimics the patterns and processes of nature, an ecological balance is fostered and the environmental footprint of the campus is reduced.

Nature-Based Learning

We integrate the principles of Nature-Based Learning (NLB). This pedagogical approach conceives the school garden as a living classroom, a dynamic space where learning transcends the limits of the classroom. The garden becomes a hands-on laboratory for teaching science, allowing students to observe life cycles, ecology, botany, and zoology firsthand. In the realm of art, nature offers inspiration for drawing, painting, sculpture, and creative expression. And in entrepreneurship, the garden can serve as a small-scale business model, where students learn about production, marketing, sales, and management, fostering practical skills and innovative thinking. This holistic approach transforms green space into a multifunctional and experiential pedagogical tool.

By combining Biophilic Design, Attention Restoration Theory, Ecological Landscaping, and Nature-Based Learning, our program offers a robust and coherent framework for the transformation of school environments, promoting not only academic success but also the holistic well-being of the educational community.

METHODOLOGY

The implementation of this five-year program (2025-2030) to transform schoolyards in the Colombian dry Caribbean follows a structured and participatory methodology, designed to maximize pedagogical, bioclimatic, and ecological impact. It ranges from initial diagnosis to replication and continuous monitoring, integrating technical knowledge with the participation of the educational community.

Phase 1: Participatory Diagnosis and Co-design (January-May 2025)

The process begins with a thorough diagnosis between January and March 2025. Drones are used to generate orthophotos and Normalized Difference Vegetation Index (NDVI) maps, allowing for accurate identification of heat islands within school campuses and determining the most suitable areas for intervention. In parallel, a soil analysis is carried out to evaluate pH and salinity, crucial

information for species selection and necessary amendments.

In April and May 2025, the diagnostic information is translated into a highly participatory co-design process. Teachers and students are actively involved in the conceptualization of the gardens. Using models and solar simulations, they experiment with different designs and configurations. This collaborative process allows them to choose species and determine their optimal location based on the projected shade and prevailing winds, ensuring that gardens fulfill their bioclimatic function effectively.

The program proposes fifteen emblematic native species, selected for their low water requirement, prolonged ornamental value and ecological benefits. These include bougainvillea *(Bougainvillea spectabilis*), prized for its brightly coloured bracts and almost year-round blooms; heliconia (*Heliconia bihai*), whose red inflorescences attract and feed hummingbirds; and sansevieria (*Sansevieria trifasciata*), a succulent known for its ability to filter volatile compounds from the air. To these are added coleus of multicolored leaves, coquettes (*Catharanthus roseus*) of continuous flowering and epiphytes such as Spanish moss (*Tillandsia usneoides*). All of these species share the characteristic of being drought-resistant and providing nectar or shelter for local wildlife.

Phase 2: Pilot Implementation and Training (June-December 2025)

The execution phase begins in June and runs until November 2025 with the pilot planting. Soils are prepared by improving them with the addition of 5% biochar, which optimizes water and nutrient retention. A high-efficiency drip irrigation system is installed to ensure sustainable water use. In this initial stage, five gardens are established, each of 150 m². The ambitious goal is to achieve a survival rate of at least 85% at 180 days after planting, which will validate species selection and management techniques.

In December 2025, intensive training is being conducted for 60 teachers. This 32-hour course addresses essential topics such as the propagation of native species, pest management through biological control, and, crucially, the pedagogical use of the new garden as a living classroom for various subjects.

Phase 3: Replication and Expansion (2026-2028)

Based on the success of the pilot phase, the model is replicated and scaled between 2026 and 2028. It expands to twenty neighboring schools, facilitating the transfer of knowledge and experience. This expansion is supported by the figure of student mentors, who, having participated in the pilot phase, guide their classmates in the new institutions. In addition, an open guide is developed that includes detailed plans, cost lists and agronomic recommendations, ensuring the replicability and sustainability of the program on a larger scale.

Phase 4: Continuous Monitoring and Adjustment (2029-2030)

A longitudinal assessment module is implemented that compares the standardized grades and scores from 2025-2029 with a control group to determine the impact of ornamental landscaping on learning; each year a time series is updated with this data, a Composite Education Index (IEC) is calculated – which integrates academic performance, retention and attendance – and changes are analysed using mixed models: an increase in the IEC ≥ 8 points validates the strategy and allows it to be scaled, an increase of 3-7 points requires minor adjustments (plant density, hours of use, etc.). curricular integration) and variations ≤ 2 points trigger a profound redesign; Findings are reported annually to the community and funders, ensuring an evidence-based process of continuous improvement.

EXPECTED RESULTS

We expect to see a significant 25% increase in student concentration. This improvement in sustained attention is crucial for academic performance and is directly attributed to the creation of more stimulating and less stressful learning environments. The presence of nature, as suggested by Attention Restoration Theory, allows

students' minds to recover, reducing cognitive fatigue and improving their ability to focus on educational tasks.

At the same time, we foresee a reduction of at least 20% in the feeling of stress perceived by students. School gardens, with their natural beauty and the tranquility they instill, act as a balm for the mind, creating spaces where students can relax and disconnect from daily pressures. This decrease in stress contributes to a more positive school environment, promoting the emotional well-being and mental health of the educational community in general.

From an ecological perspective, we project a remarkable 35% increase in bee and butterfly visits to school gardens. The selection of native species, rich in nectar and pollen, will establish these spaces as vital microhabitats for local pollinators. This increase in biodiversity is not only an indicator of the health of the garden ecosystem, but also offers unique opportunities for hands-on learning about ecology, the importance of pollinators in ecosystems, and the interconnectedness of life.

On an economic level, the programme has an extremely promising school bioeconomy component. Each school nursery plans to produce 15,000 seedlings of native species annually. This mass production not only ensures the availability of plant material for the expansion of the gardens in the same school and in neighboring institutions, but also represents an innovative source of financing. The sale of these seedlings will finance the purchase of supplies needed for garden maintenance and, equally important, generate additional income for extracurricular activities and educational projects. This transforms the gardens into centers of entrepreneurial learning, where students acquire practical skills in production, management, and marketing.

In the climatic field, the new green canopies generated by the gardens are designed to have a direct impact on the thermal comfort of the courtyards. We anticipate a decrease of at least 2°C in the radiant temperature of the patio, especially during the critical hours of greatest sunshine. The shade cast by vegetation, combined with the evapotranspiration cooling effect of plants, will transform these arid spaces into cooler and more pleasant areas. This bioclimatic improvement will not only make the playgrounds more comfortable for play and recreation, but will also allow for greater use of outdoor spaces as outdoor classrooms, expanding pedagogical possibilities and improving the quality of life on campus.

In summary, after a year, we expect the native ornamental gardens program to prove to be a multifaceted investment with significant returns in the educational

quality, student well-being, ecological health, economic sustainability, and environmental comfort of schools in the Colombian Caribbean.

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