Assessment of the Feasibility and Sustainability of Vertical Farming in Compact Urban Spaces

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1. Introduction

Rapid urbanisation poses challenges for food security, environmental sustainability and urban living. Vertical farming, which grows plants in stacked layers, offers a promising solution for dense cities by optimising space and resource use. This report compares vertical and horizontal systems, focusing on water-use efficiency and plant growth rates.

2. Research Objectives

The main objectives of the present study are:

- To assess the technical and environmental feasibility of vertical farming in limited-space environments.
- To compare vertical and horizontal farming in terms of plant growth rate and water-use efficiency.

3. Theoretical Framework

Vertical farming has been increasingly established as an innovative strategy within the field of urban agriculture, incorporating concepts from permaculture (permanent culture), agroecology and environmental engineering. According to Despommier (2010), vertical farming enables intensive food production without the need for large land areas, thereby contributing to the reduction of each individual's ecological footprint.

4. Materials and Methods

The investigation was carried out over a period of three months in an urban experimental space with controlled lighting, temperature and ventilation conditions. Two cultivation systems were employed:

- Horizontal System (HS): cultivation in horizontal containers (repurposed milk cartons) using substrate.
- Vertical System (VS): modular vertical structure for cultivation (repurposed milk cartons) using substrate.

4. Materials and Methods

In the initial phase of the study, an experimental sowing was carried out using a variety of plant species, with the aim of identifying those best suited to the environmental conditions and specific objectives of the research. This preliminary stage made it possible to assess germination rates, early growth speed and seedling robustness under controlled conditions.

Photographs of the experimental sowings carried out between October and December, as part of the first phase of the investigation, involving various plant species.

4. Materials and Methods

Material	Description/Use
Empty milk cartons	Reused containers for cultivation (both vertical and horizontal arrangements)
Inverted graduated tubes	Automatic irrigation system
Ruler	Measurement of plant height
Substrate	Plant growth medium (soil)
Certified seeds	Ensure uniformity and quality of cultivated species
Artificial light (horticultural LED)	Supplementary lighting in environments with insufficient natural light – autumn
Precision balance	Weighing plants to assess fresh biomass at the beginning of the experiment and soil weight
Camera / Mobile phone	Visual documentation of plant development
Auxiliary containers (e.g., seed trays)	Used during the initial germination phase
Data analysis software (Excel)	Processing and statistical interpretation of data

4. Materials and Methods - Preliminary Phase and Student Involvement in the Vertical Garden Project

- **Initial Experimental Sowing**:

  A range of plant species was sown experimentally to identify those best suited to the project's specific conditions and goals.

- **Evaluation Criteria**:

  Germination rates, early growth speed, and seedling vigour were observed under controlled conditions.

- **Student Participation – Eco-Schools Club**:

  Students actively launched the vertical garden project, replicating the sowing process to assess species suitability within the real-life implementation environment.

4. Materials and Methods

The parameters assessed included:

- Growth rate (cm/week)
- Plant colouration (changes in colour over the course of the experiment)
- Water-use efficiency (mL consumed per week)

Measurements were taken on a weekly basis, and the data were analysed statistically.

4. Materials and Methods

An automatic irrigation system was used, featuring an inverted graduated tube, which maintained soil moisture for longer periods while preventing overwatering

5. Results

Vertical System:

Butterhead Lettuce (*Lactuca sativa*)

Data	Plant Height (cm)	Changes in leaf colour	Water Consumption (mL/week)	Observations
12/02/2025	2,1	Light green	120	Germination started
19/02/2025	4,5	Light green	110	Steady growth
26/02/2025	7,2	Green	115	Leaves widened
05/03/2025	9,8	Deep green	130	Good light exposure
12/03/2025	12,0	Deep green	125	Consistent development
19/03/2025	14,5	Deep green	130	Height stabilised
26/03/2025	15,2	Green	120	First leaves harvested
02/04/2025	15,5	Green	115	System maintenance
09/04/2025	15,7	Slightly pale green	110	End of harvest cycle

5. Results

Horizontal System:

Butterhead Lettuce (*Lactuca sativa*)

Data	Plant Height (cm)	Changes in leaf colour	Water Consumption (mL/week)	Observations
12/02/2025	1,8	Light green	140	Initial germination
19/02/2025	3,9	Light green	135	Slow growth
26/02/2025	6,5	Yellowish green	130	Reduced sunlight exposure
05/03/2025	8,2	Green	145	Improved ventilation
12/03/2025	10,5	Deep green	150	More uniform growth
19/03/2025	12,1	Deep green	150	Good substrate adaptation
26/03/2025	13,0	Green	140	First leaves harvested
02/04/2025	13,3	Slightly pale green	135	Irrigation system adjusted
09/04/2025	13,5	Pale green	130	Signs of substrate depletion

5. Results

Vertical System:

Parsley (*Petroselinum crispum*)

Data	Plant Height (cm)	Changes in leaf colour	Water Consumption (mL/week)	Observations
12/02/2025	1,8	Light green	100	Uniform germination
19/02/2025	3,8	Light green	105	Balanced growth
26/02/2025	6,1	Green	110	Good light exposure
05/03/2025	8,6	Green	115	Broader leaves
12/03/2025	10,8	Deep green	120	Strong leaf density
19/03/2025	12,6	Deep green	118	Efficient irrigation system
26/03/2025	13,9	Deep green	115	Potential for partial harvesting
02/04/2025	14,2	Green	110	Continued growth maintenance
09/04/2025	14,5	Slightly pale green	105	Plants ready for full harvest

5. Results

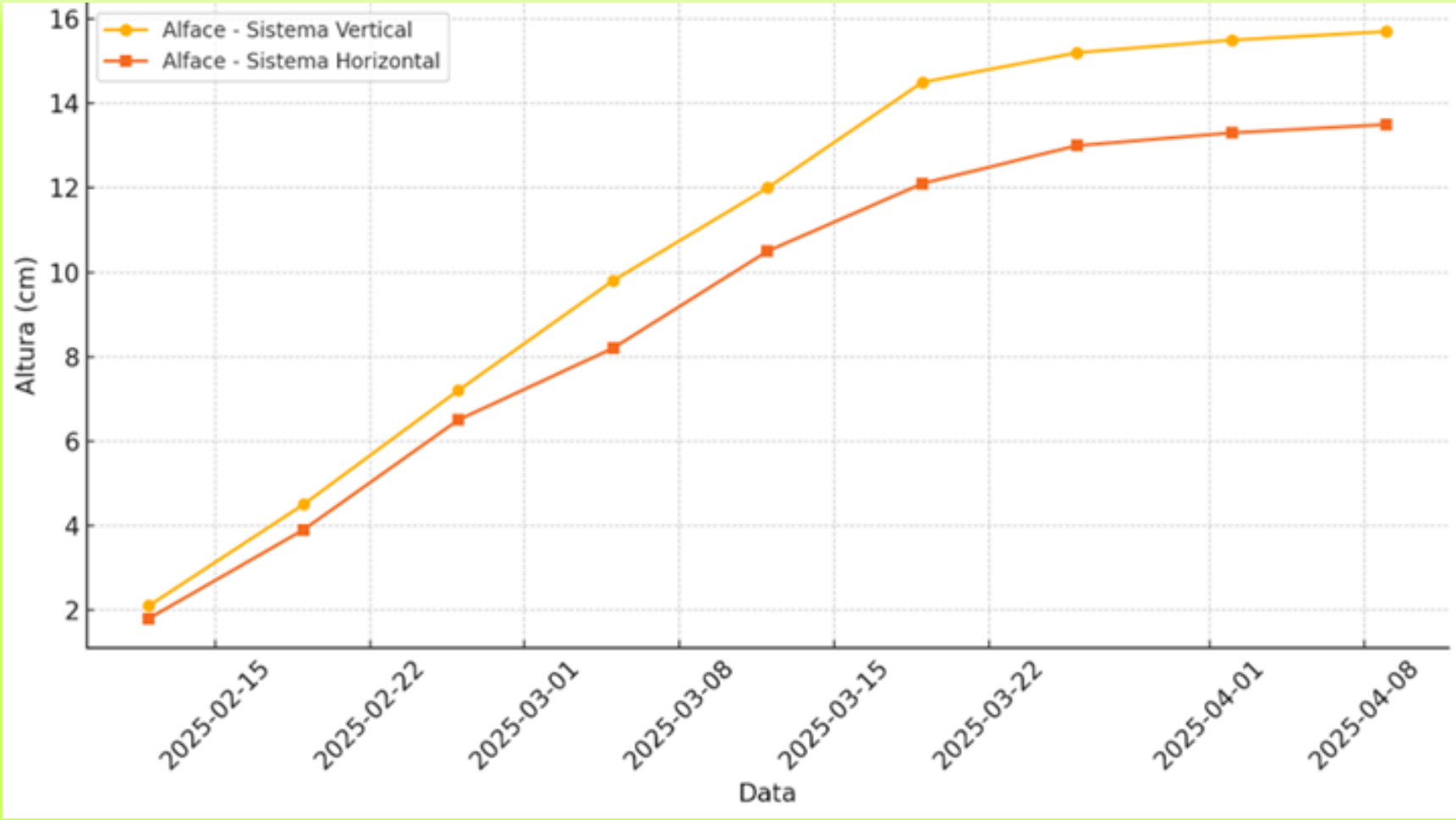
Horizontal System:

Parsley (*Petroselinum crispum*)

Data	Plant Height (cm)	Changes in leaf colour	Water Consumption (mL/week)	Observations
12/02/2025	1,5	Light green	110	Recent germination
19/02/2025	3,2	Yellowish green	120	Slow growth
26/02/2025	5,0	Light green	125	Plants still young
05/03/2025	7,1	Green	130	Increased leaf density
12/03/2025	9,3	Green	130	More robust leaves
19/03/2025	11,0	Deep green	135	Good response to irrigation
26/03/2025	12,4	Deep green	130	Possible start of partial harvest
02/04/2025	13,1	Green	125	Regular maintenance
09/04/2025	13,5	Slightly pale green	120	Reduced growth rate

6. Results and Discussion

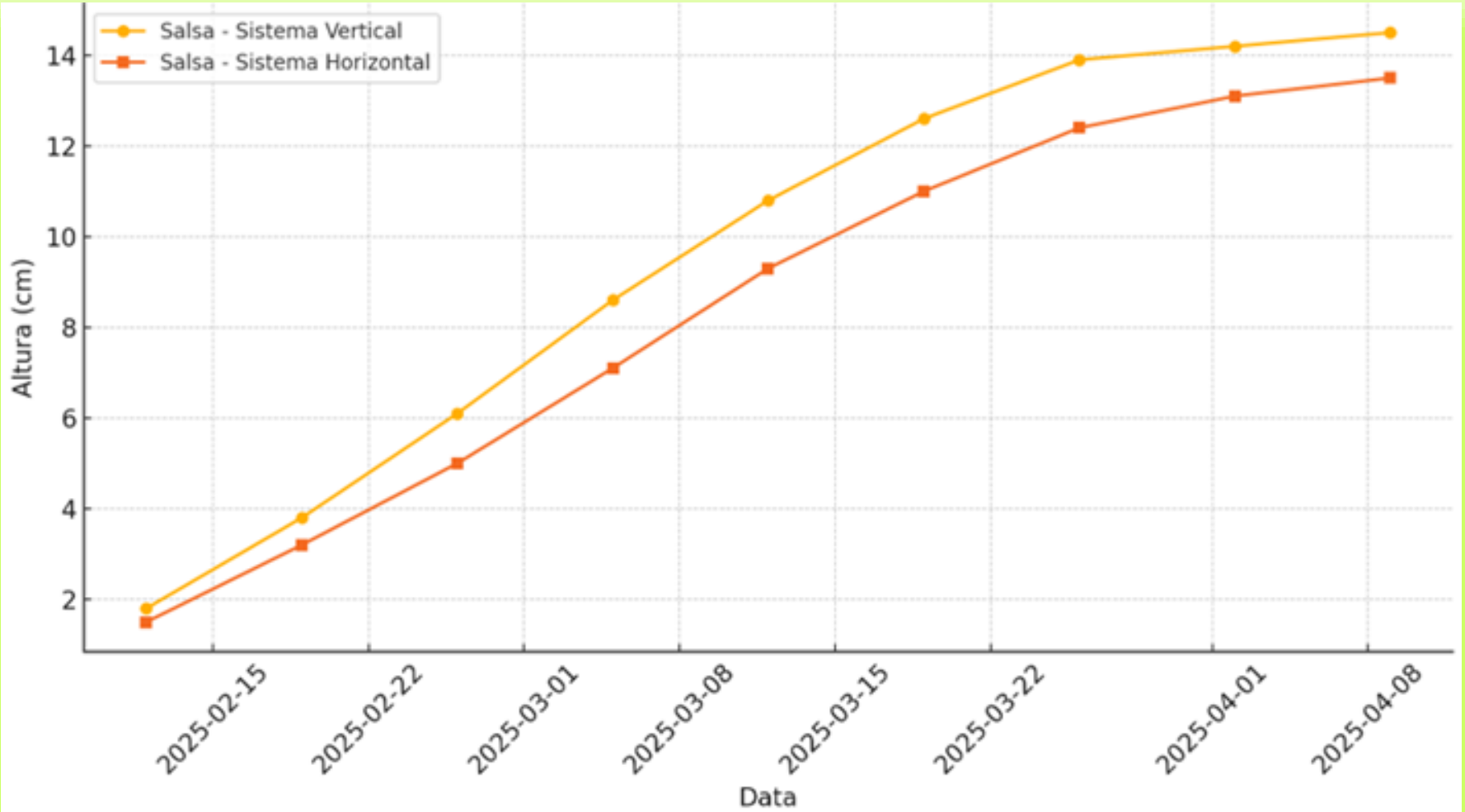
Vertical System
Horizontal System



Graph 1, which compares the growth rate (cm/week) of butterhead lettuce (*Lactuca sativa*) in the vertical and horizontal systems.

6. Results and Discussion

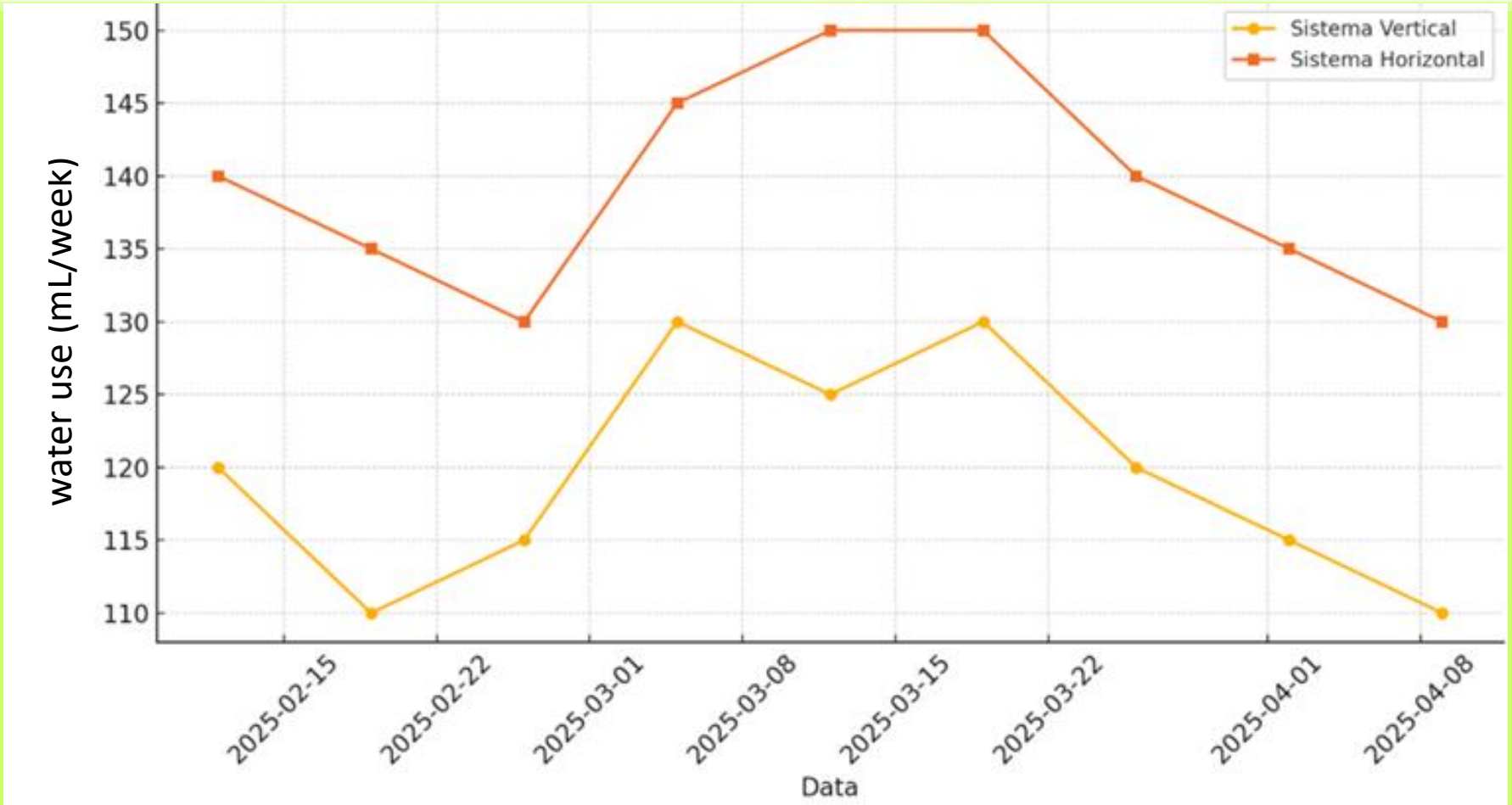
Vertical System
Horizontal System



Graph 2, which compares the growth rate (cm/week) of parsley (*Petroselinum crispum*) in the vertical and horizontal systems.

6. Results and Discussion

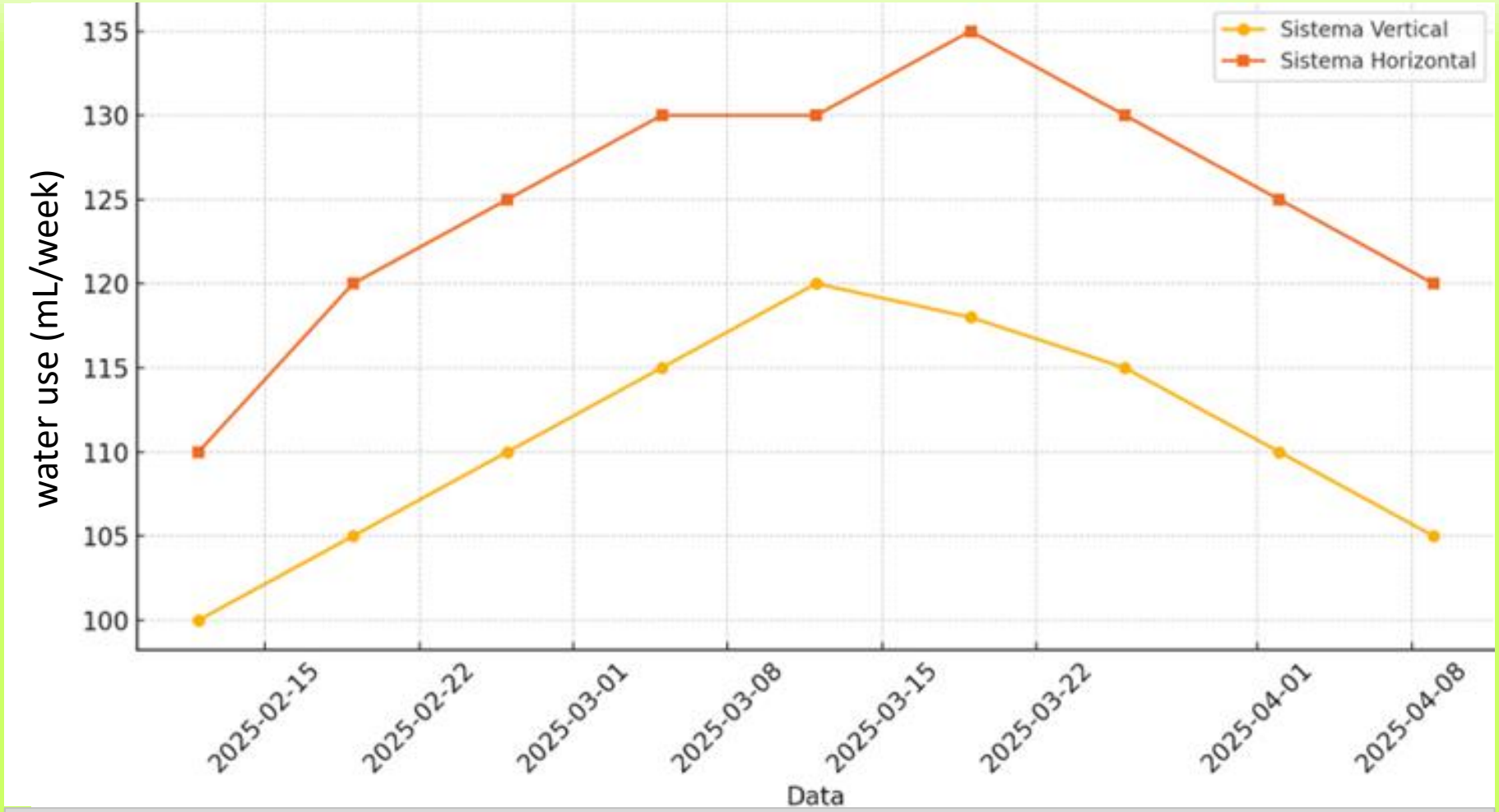
Vertical System
Horizontal System



Graph 3, which compares the water use (mL/week) of butterhead lettuce (*Lactuca sativa*) between the vertical and horizontal systems.

6. Results and Discussion

Vertical System
Horizontal System



Graph 4, which shows the comparison of water use (mL/week) of parsley (*Petroselinum crispum*) between the vertical and horizontal systems.

6. Results and Discussion

Study Findings:

- A comprehensive analysis of the feasibility of vertical farming as a practical and sustainable solution for growing aromatic plants at home.
- The vertical system offers clear advantages over traditional horizontal setups, particularly in terms of:
  - Improved water-use efficiency
  - Enhanced morphological characteristics of the plants

Significance:

- Enables high-quality, vigorous plant growth in small spaces
- Effectively meets the demands of modern urban living

6. Results and Discussion

Key Features Observed in Vertically-Grown Plants:

- More robust and healthier appearance
- Deeper colouration, typically associated with:
  - Higher chlorophyll content
  - Potential increase in essential oil concentration

Implications:

- Enhanced aromatic and culinary value
- Visual indicators of plant vitality and functional yield

6. Results and Discussion

Practical and Aesthetic Advantages of Vertical garden

- **Enhanced Plant Growth**:

Vertical systems promote the development of larger leaves and taller plants, indicating improved growing conditions such as better light distribution and efficient water use.

- **Ease of Harvest and Yield Optimisation**:
- Increased leaf size makes harvesting easier and boosts per-plant productivity—particularly valuable in domestic contexts.

- **Aesthetic Appeal**:

Vigorous, lush, and colourful foliage enhances the visual attractiveness of the system, which is especially important in visible areas such as balconies, kitchens, or indoor gardens.

6. Results and Discussion

Vertical garden as a Sustainable Domestic Solution

- **Efficient Use of Space and Light**:

Vertical arrangements are ideal for homes with limited sunlight, as units can be placed near windows or bright façades.

- **Initial Investment vs Long-Term Benefits**:

While vertical systems may require a higher upfront cost and basic technical know-how, the improved quality and efficiency justify the investment.

- **Sustainability and Food Autonomy**:

Vertical herb cultivation supports sustainable diets, encourages environmental awareness, and promotes greater household food independence.

7. Conclusions

Vertical garden as a Viable and Sustainable Solution

- **Research Findings**:
  - Vertical cultivation has been shown to be a viable and sustainable method for growing plants in limited spaces.
- **Key Advantages over Horizontal Systems**:
  - Notable improvements include more efficient water use and increased productivity.

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