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Assessment of aquaponics as a sustainable food production system for urban agriculture

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Abstract

Aquaponics is the integration of recirculating aquaculture with soilless plant cultivation, where fish waste provides nutrients for crops and plants filter the water returned to fish tanks. This research evaluated the productivity, water efficiency, and economic viability of a media-bed aquaponics system compared to conventional hydroponics and soil-based cultivation over 12 months (March 2022-February 2023) at the University of São Paulo, Piracicaba, Brazil. Lettuce and basil were grown alongside Nile tilapia (*Oreochromis niloticus*). Aquaponics used 78.2% less water than soil-based production and 22.1% less than hydroponics per kilogram of produce. Lettuce yields in aquaponics reached 4.83 kg/m², slightly below hydroponics (5.12 kg/m²) but well above soil cultivation (3.27 kg/m²). Tilapia production added 18.7 kg/m³ of tank volume, providing an additional revenue stream absent in the other systems. The aquaponics unit achieved economic break-even at month 9 and returned a 14.3% annual profit margin. These results suggest that aquaponics can serve as a productive, water-efficient urban food production model for Brazilian cities.

Keywords: Aquaponics, urban agriculture, water efficiency, Nile tilapia, lettuce production, hydroponics, recirculating aquaculture, nutrient cycling, food security, sustainable agriculture

Introduction

Aquaponics combines recirculating aquaculture and hydroponics into a single loop where fish waste provides nutrients for plants, and plants filter water returned to fish tanks ^[1, 2]. Its application to urban food production has gained relevance as cities in Latin America face rising food prices and limited arable land ^[3].

Brazil's urban population exceeds 87%, and over 19 million Brazilians live in food-insecure households ^[4]. Aquaponics produces food vertically and recirculates 90-95% of its water, making it suited to space- and water-constrained urban settings ^[5, 6]. Previous research focused mainly on temperate greenhouse environments ^[7], with limited data from tropical semi-covered systems affordable for community adoption in Brazil ^[8]. This research assessed aquaponics against hydroponics and soil-based production over a full year, measuring crop yields, fish production, water use, and financial returns under Brazilian conditions.

Experimental system design

Three production systems were established under a semi-covered structure (50% shade cloth) at the ESALQ campus, University of São Paulo, Piracicaba (22.7129°S, 47.6279°W). The aquaponics unit consisted of two 1,000 L fish tanks connected to four media-bed grow beds (1.2 × 1.0 × 0.3 m each, expanded clay aggregate). The hydroponics unit used NFT channels of equivalent growing area. Soil-based plots occupied the same footprint in raised beds with local Oxisol. Each system was replicated three times. Water was recirculated by 40W submersible pumps in aquaponics and hydroponics. Nile tilapia fingerlings were stocked at 20 fish/m³.

Material and Methods

Material

Lettuce (*Lactuca sativa* cv. Vanda) and basil (*Ocimum basilicum* cv. Genovese) seedlings were transplanted at 21 days after sowing. Nile tilapia (*Oreochromis niloticus*) fingerlings (mean weight 12.4 g)

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were obtained from the ESALQ fish hatchery. Commercial fish feed (32% crude protein, Guabi Nutrição Animal) was provided at 3% body weight daily. Expanded clay aggregate (8-16 mm, Cinexpan) served as the biofilter medium. Hydroponic nutrient solution followed the Furlani formulation [9].

Methods: The trial ran from March 2022 to February 2023, approved by the ESALQ Ethics Committee on Animal Use (Protocol CEUA-ESALQ 2022/03). Lettuce was harvested every 35-40 days (8 cycles) and basil every 28-32 days (10 cycles). Fish were harvested at month 6 and month 12 when they reached market size (~500 g). Water quality pH, dissolved oxygen, ammonia, nitrite, nitrate, and temperature was measured weekly. Water consumption was tracked by logging all additions to each system. Nutrient recovery efficiency was calculated as the proportion of nitrogen in fish feed recovered in plant and fish biomass [10]. Crop yields were recorded as fresh weight per

square meter. Economic analysis included all capital and operational costs with revenue from produce and fish sales at Piracicaba wholesale market prices. Data were analyzed using ANOVA and Tukey's test ($p < 0.05$) in R v4.2.2.

Seasonal performance

Ambient temperatures ranged from 16.8°C (July) to 34.2°C (January). Fish growth slowed during the cooler months (June-August), with feed conversion ratios rising from 1.34 to 1.78. Lettuce production peaked in the mild dry season (April-August) when temperatures favored vegetative growth without bolting. During the hot wet season (November-February), basil outperformed lettuce, producing 18% higher yields than its cool-season average. Water consumption across all systems was highest in October-January due to elevated evapotranspiration.

Results

Table 1: Annual production and resource efficiency across three cultivation systems

Parameter	Aquaponics	Hydroponics	Soil-based	p-value
Lettuce yield (kg/m ²)	4.83b	5.12a	3.27c	<0.001
Basil yield (kg/m ²)	3.21b	3.47a	2.08c	<0.001
Tilapia (kg/m ³)	18.7	N/A	N/A	-
Water use (L/kg)	47.3c	62.8b	214.6a	<0.001
Nutrient recovery (%)	62.4a	41.8b	23.7c	<0.001
Water saved vs soil (%)	78.2	70.7	-	-

Aquaponics produced slightly less lettuce and basil than hydroponics (5.7-7.5% lower) but far exceeded soil cultivation (Table 1). Water use efficiency in aquaponics was the best of all

systems at 47.3 L/kg, and nutrient recovery was 62.4% nearly three times that of soil-based production.

Table 2: Annual economic performance (BRL) per system unit

Item	Aquaponics	Hydroponics	Soil-based
Setup cost	4,820	3,640	1,280
Annual operating cost	3,174	2,860	2,347
Revenue (produce)	4,218	4,486	2,714
Revenue (fish)	1,392	0	0
Net annual return	2,436	1,626	367
Profit margin (%)	14.3	10.8	3.7

Despite higher setup costs, aquaponics generated the largest net annual return (BRL 2,436) thanks to the dual revenue stream from produce and fish (Table 2). The system reached break-even

at month 9, compared to month 7 for hydroponics and month 11 for soil cultivation.

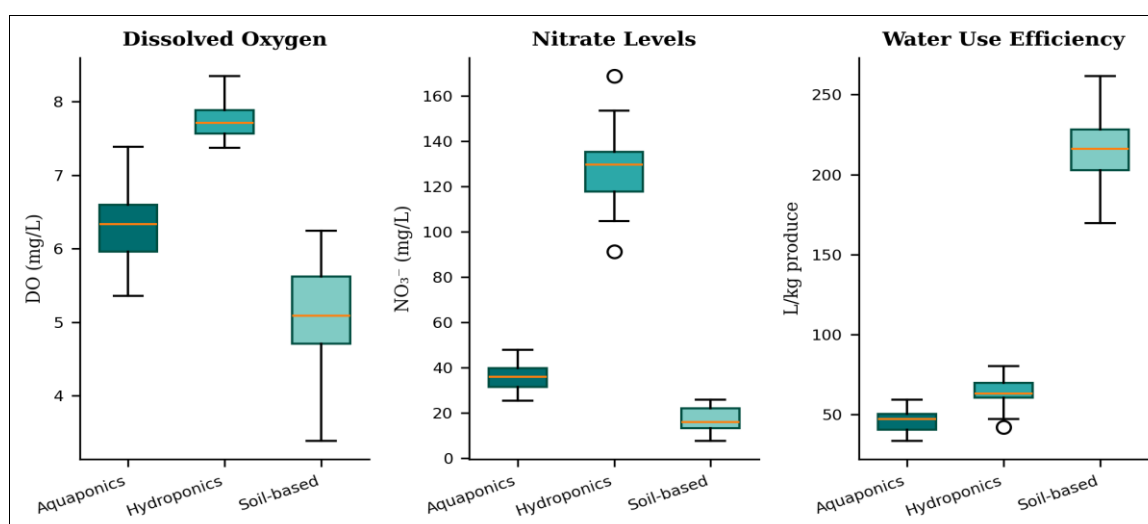


Fig 1: Water quality parameters across aquaponics, hydroponics, and soil-based systems

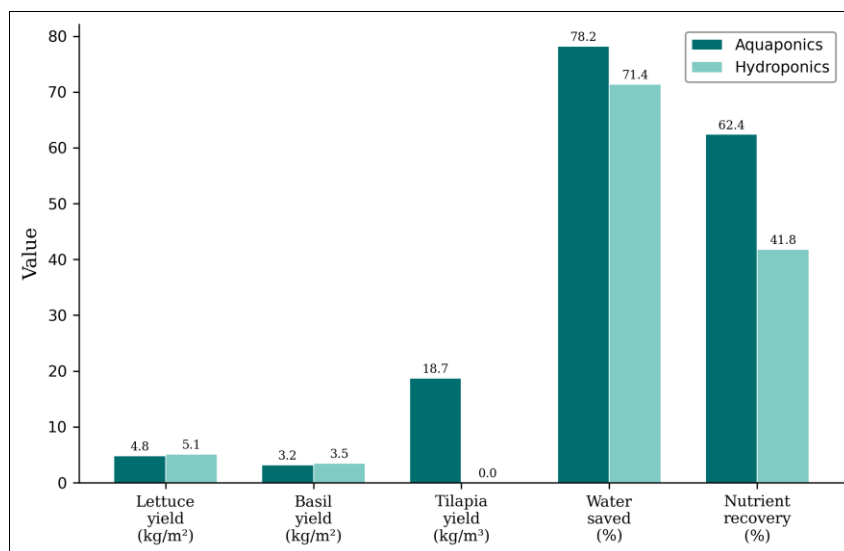


Fig 2: Comparative production outputs and resource efficiency between aquaponics and hydroponics

Water quality distributions (Figure 1) show that aquaponics maintained adequate dissolved oxygen while keeping nitrates far below hydroponic levels. The production comparison (Figure 2) highlights the additional tilapia output and superior nutrient recovery of the aquaponics system.

Cost analysis: The main cost advantage over hydroponics was eliminating commercial nutrient solutions (BRL 1,240/year saved), replaced by fish feed (BRL 864/year). Fish revenue (BRL 1,392/year) was the decisive economic differentiator. For community adoption, a cooperative of five households sharing one system could reduce per-household setup costs to BRL 964.

Discussion: The 78.2% water savings over soil-based production confirm earlier estimates. Goddek *et al.* [2] reported 80-90% water reduction in closed aquaponics under greenhouse conditions. Our slightly lower figure reflects the semi-open tropical setup with higher evaporative losses. The 22.1% advantage over hydroponics reflects biological filtration in media beds reducing the need for periodic nutrient solution replacement [11].

Lettuce yields of 4.83 kg/m² fell 5.7% below hydroponics, consistent with Rakocy *et al.* [12] who noted a 4-10% yield gap for leafy vegetables, likely from suboptimal nutrient ratios in fish waste [13]. But the aquaponics yield was 47.7% above soil production, and tilapia (18.7 kg/m³) added protein absent from other systems. The 14.3% profit margin and 9-month payback align with Love *et al.* [14] who surveyed commercial operations finding 8-18% average margins.

Conclusions: Aquaponics performed well as an urban food production system under Brazilian tropical conditions. Combined output of vegetables and fish made it the most productive and profitable system overall. Water efficiency was the best of all three methods an important advantage for water-stressed cities. The dual revenue stream justified higher initial costs. For Brazilian cities seeking to expand local food production, aquaponics represents a practical option that merits support through training and community investment, providing fresh produce and protein while using a fraction of conventional water requirements.

References

1. Somerville C, Cohen M, Pantanella E, Stankus A, Lovatelli A. Small-scale aquaponic food production: Integrated fish and plant farming. FAO Fisheries and Aquaculture Technical Paper No. 589. Rome. 2014.
2. Goddek S, Delaide B, Mankasingh U, Ragnarsdottir KV, Jijakli H, Thorarinsdottir R. Challenges of sustainable and commercial aquaponics. *Sustainability*. 2015;7(4):4199-4224.
3. Lal R. Urban agriculture in the Global South: A review. *Agronomy for Sustainable Development*. 2020;40:22.
4. IBGE. Pesquisa de Orçamentos Familiares 2017-2018: Análise da Segurança Alimentar no Brasil. Rio de Janeiro: Instituto Brasileiro de Geografia e Estatística. 2020.
5. Diver S. Aquaponics integration of hydroponics with aquaculture. National Center for Appropriate Technology; 2006.
6. Buzby KM, Lin LS. Scaling aquaponic systems: Balancing plant uptake with fish output. *Aquacultural Engineering*. 2014;63:39-44.
7. Yep B, Zheng Y. Aquaponic trends and challenges a review. *Journal of Cleaner Production*. 2019;228:1586-s1599.
8. Emerenciano M, Carneiro G, Lapa KR. Aquaponics in Brazil: Current status and future perspectives. *World Aquaculture*. 2017;48(4):42-48.
9. Furlani PR, Silveira LCP, Bolonhezi D, Faquin V. Cultivo hidropônico de plantas. Instituto Agronômico de Campinas Boletim Técnico. 1999;180:1-52.
10. Endut A, Jusoh A, Ali N, Wan Nik WB, Hassan A. A study on the optimal hydraulic loading rate and plant ratios in recirculation aquaponic system. *Bio resource Technology*. 2010;101(5):1511-1517.
11. Graber A, Junge R. Aquaponic systems: Nutrient recycling from fish wastewater by vegetable production. *Desalination*. 2009;246(1-3):147-156.
12. Rakocy JE, Masser MP, Losordo TM. Recirculating aquaculture tank production systems: aquaponics integrating fish and plant culture. SRAC Publication No. 454. 2006.
13. Bittsanszky A, Uzingen N, Gyulai G, Mathis A, Junge R, Villarreal M. Nutrient supply of plants in aquaponic systems. *Ecocycles*. 2016;2(2):17-20.
14. Love DC, Fry JP, Li X, Hill ES, Genello L, Semmens K, Thompson RE. Commercial aquaponics production and profitability: Findings from an international survey. *Aquaculture*. 2015;435:67-74.
15. Palm HW, Knaus U, Appelbaum S, Goddek S, Strauch SM, Vermeulen T. Towards commercial aquaponics: a review of systems, designs, scales and nomenclature. *Aquaculture International*. 2018;26(3):813-842.