ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25aug359

Design of an Agri-Tech Community Center for Food Self-Sufficiency in the City of Yoko

Tsanga Nkoula Pie Achille Stéphane[1] ; Tsambang Cédrix[2] ; Bwemba Charles[3]

[1]MArch in Building Engineering and Architecture, Department of Architecture, National School of Public Works, Yaoundé, Cameroon,
[2]Sustainable Architect, ONAC 378, Cameroon,
[3]Doctor of Civil Engineering, Lecturer, Department of Architecture, National School of Public Works, Yaoundé, Cameroon,

Publication Date: 2025/08/14

Abstract: Rapid urbanization, socio-economic challenges, and climate change demand innovative approaches to urban food systems in African contexts. This study presents the design and development of an Agri-Tech Community Centre in Yoko, Cameroon, aiming to enhance urban food autonomy through integrated architectural solutions. Using a design-based research methodology, the project employs modular and holonic principles to create a flexible, scalable, and context-responsive architectural model. The centre combines agricultural production, processing, education, and community spaces, embedding technologies such as hydroponics, aquaponics, and biofacades within sustainable building practices using locally available materials. The design promotes circular resource management, social empowerment, particularly for youth and women, as well as spatial revitalization of underused urban land. While the model shows high potential for ecological, social, and economic impact, limitations include economic feasibility assessments and governance mechanisms that require further study. This work redefines the architect's role as a mediator of urban resilience and food sovereignty, offering a replicable framework for integrating agriculture into African urban environments. The findings encourage interdisciplinary collaboration to foster sustainable, productive, and equitable cities.

Keywords: *Sustainable Architecture, Urban Agriculture, Food Self-Sufficiency, Yoko.*

How to Cite: Tsanga Nkoula Pie Achille Stéphane ; Tsambang Cédrix ; Bwemba Charles (2025), Design of an Agri-Tech Community Center for Food Self-Sufficiency in the City of Yoko. *International Journal of Innovative Science and Research Technology*, 10(8), 316-323. https://doi.org/10.38124/ijisrt/25aug359

I. INTRODUCTION

Urban areas are increasingly confronted with the challenge of food security, particularly in developing countries where rapid urbanization, combined with underperforming traditional agricultural systems, generates significant vulnerabilities. In Africa, this challenge is amplified by high population growth, limited natural resource management, and growing dependence on food imports (IFC, 2020). At the same time, urbanization often results in underutilized spaces that could be repurposed for food production through urban agriculture. Architecture, as an innovative and structuring discipline, can play a key role in redefining urban food systems. Modular architecture, with its capacity for adaptability and sustainability, together with holonic design principles, rooted in fractal and systemic approaches, offers the potential to create self-sufficient, regenerative, and interconnected urban environments (Bonthoux et al., 2021).

By 2050, the United Nations estimates that nearly 60% of Africa's population will reside in cities, intensifying pressures on infrastructure and food supply chains (Ficou, 2025). This demographic trend is likely to exacerbate food inequalities, especially in peripheral urban zones often referred to as "food deserts". Yet, African cities hold untapped potential for urban agriculture, which could be a cornerstone of local food self-sufficiency. Despite this, current architectural approaches remain limited, relying mainly on isolated or small-scale interventions without an integrated framework combining architectural and agricultural dimensions (Rafiei, 2012).

Integrating urban agriculture into architectural design could help address pressing challenges such as food security, sustainable urban land use, and resilience to economic and environmental crises. However, existing literature often addresses the issue from either a technical or social perspective, with little exploration of modular and holonic design as tools for large-scale urban agricultural integration. This study seeks to bridge this gap by proposing an integrated, systemic framework linking architectural principles with agricultural production, adapted to the African urban context.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25aug359

The central research question is: *How can architecture through modular and holonic design facilitate the integration of urban agricultural spaces in African cities to foster food self-sufficiency?*

To address this, the study focuses on three key objectives:

- To propose an architectural framework for integrating urban agriculture based on modular and holonic design principles;
- To identify Africa-specific challenges and develop solutions adapted to socio-economic, climatic, and cultural constraints;
- To evaluate the potential of these approaches to enhance the sustainability and food autonomy of urban neighborhoods.
- By combining architectural innovation with urban agriculture, this research aims to contribute to the expansion of architectural design practices capable of addressing the pressing food security challenges of African cities.

II. LITERATURE REVIEW

A. Urban Food Insecurity and the African Context

Urban food insecurity in Africa is the result of complex structural and environmental factors, including rapid urbanization, fragmented supply chains, informal economies, and under-resourced infrastructure. According to the UN-Habitat, the majority of urban growth in Africa occurs in peripheral areas with limited access to healthy, affordable food, creating so-called *food deserts*. While policies increasingly recognize urban agriculture as a resilience mechanism (FAO, 2019), practical integration within urban planning and architecture remains limited, often constrained by land tenure issues, socio-political fragmentation, and infrastructural deficits (Kamga et al., 2021).

B. Urban Agriculture: Benefits and Limits of Current Approaches

Urban agriculture is widely documented for its environmental, social, and economic benefits: reduction of food miles, recycling of organic waste, community empowerment, and local income generation. However, much of the literature focuses on bottom-up or informal practices, community gardens, or pilot projects at small scales. These models rarely scale up due to the lack of systemic integration into city-making frameworks. Additionally, architectural considerations, such as spatial configurations, vertical integration, water reuse, or modular adaptability are often overlooked or treated as after thoughts (Rafiei, 2012). There is a pressing need to shift from isolated projects to a more holistic and design-driven urban agricultural paradigm.

C. Modular Architecture: Flexibility, Replicability, and Sustainability

Modular architecture has gained traction for its ability to provide flexible, time-efficient, and resource-conscious construction solutions. In the context of housing, emergency response, and infrastructure, modular systems offer scalability and adaptability, attributes increasingly valued in urban resilience discourse. The application of modular principles to food production infrastructure, however, remains underexplored. Some recent innovations in agro-modular design, such as shipping container farms or modular rooftop systems, suggest that architecture could become a key facilitator of urban food production, particularly in space-constrained environments.

D. Holonic Design: A Systems Thinking Approach to build Environments

Holonic design, rooted in Arthur Koestler's concept of *holons*, entities that are simultaneously wholes and parts of larger systems, offers a promising framework for regenerative and adaptive urban design. Applied to architecture, holonic thinking supports decentralization, interdependence, and layered organizational structures, enabling built environments to evolve with socio-environmental needs. In the context of food systems, holonic design could facilitate the creation of nested, autonomous, yet interconnected urban farming units, functioning across neighborhood, district, and city scales. Despite its potential, this paradigm remains largely theoretical in African architectural research.

E. Research Gap

While literature on urban agriculture, modular design, and systems-based thinking is growing, few studies attempt to merge these domains within the African urban context. Existing architectural research often addresses housing, sanitation, or energy, but not food. Moreover, the application of holonic principles to food architecture remains underdeveloped, particularly in the Global South. There is a critical need to investigate how spatial design can operationalize food self-sufficiency through modularity, system integration, and cultural relevance. This paper addresses this gap by proposing an architectural framework that combines modular and holonic approaches for resilient urban agriculture in African cities.

III. METHODOLOGY

This study adopts a qualitative, design-based research approach, combining architectural analysis, conceptual modelling, and contextual adaptation. It aims to develop an integrated framework for incorporating urban agriculture into African cities through modular and holonic design strategies. The methodology unfolds in three main phases:

A. Literature and Case Study Review

A comprehensive literature review was conducted to examine key concepts related to urban agriculture, modular architecture, and holonic design. This was complemented by the analysis of international and African case studies, focusing on existing practices of integrating agriculture within urban settings. Selected cases were evaluated based on scalability, spatial integration, socio-environmental impact, and architectural innovation. These insights informed the development of criteria for resilient and adaptable urban agricultural systems.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25aug359

B. Conceptual Framework Development

Building on the findings from the first phase, a conceptual framework was developed to guide the integration of urban agriculture into modular and holonic architectural forms. This framework includes design principles, spatial organization models, and functional typologies. It emphasizes decentralized food production, systemic interconnectivity, and adaptability to local African contexts, particularly in terms of climate, culture, land use, and socio-economic conditions.

C. Design Proposal and Impact Assessment

Using the framework, a series of architectural design propositions were created, illustrating potential implementations at the neighborhood and building scale. These proposals include schematic layouts, modular configurations, and spatial scenarios for urban food production. A qualitative impact assessment was then carried out, evaluating the proposals in terms of food autonomy potential, spatial efficiency, socio-environmental sustainability, and alignment with local urban realities.

This methodological process is grounded in architectural thinking, but also informed by urban studies, sustainability science, and systems theory. By integrating these perspectives, the study offers a replicable approach for architects, urban planners, and policymakers seeking to address food insecurity through built environment innovations in African cities.

IV. RESULTS

The design-based research culminated in a comprehensive architectural proposal for an Agri-Tech Community Center in Yoko, grounded in modular and holonic design principles. This section presents the research and design outcomes across five interconnected dimensions: territorial diagnosis, functional programming, architectural conception, systems integration, and projected impacts on territory and community.

A. Territorial Diagnosis and Site Analysis

The project site is situated in Yoko, a rural municipality in Cameroon characterized by significant agricultural potential yet limited infrastructural and spatial frameworks for agri-tech innovation. A spatial and socio-economic diagnostic identified key constraints and opportunities:

- Dispersed and underused land parcels in central Yoko
- Lack of structured food markets or agro-processing zones
- High youth unemployment and rural exodus despite agricultural resources
- A need for multifunctional spaces blending education, innovation, and production
- Environmental factors such as water accessibility, topography, and solar orientation were also analyzed to inform the site layout and functional clustering. Figure a. Refer table 1.

B. Modular and Functional Programming Model

The architectural program was structured around four primary holons or functional clusters, each designed to operate autonomously while contributing to the integrated system:

- *Production Holon:*
  Open-field agriculture, hydroponic greenhouses, composting stations, rooftop farming

- *Transformation Holon:*
  Food processing units, storage, packaging, and composting facilities

- *Education and Community Holon:*
  Training spaces, classrooms, library, community hall, digital labs

- *Market and Social Interface:*
  Farmers' square, public kitchen, multi-use market hall

This zoning ensures clear separation of flows, pedestrian, machinery, and product circulation, while promoting permeability and progression from public to private spaces. Figure b and c.
Refer table 2.

C. Architectural Conception and Materiality

The design employs a modular grid system enabling phased growth and adaptability, inspired by holonic principles. Passive bioclimatic strategies such as cross-ventilation, solar shading, rainwater harvesting, and earth-based materials enhance environmental performance and cost-effectiveness.

Key material choices focus on local availability and low carbon footprint:

- Compressed Stabilized Earth Blocks (CSEB)
- Bamboo structural elements
- Recycled metal sheeting for roofing and cladding
- The modular frame uses prefabricated components to facilitate phased construction and maintenance. Figure d.

D. Technological and Ecological Systems Integration

The architectural design incorporates context-adapted low-tech innovations to foster sustainability and resilience:

- Circular resource systems including waste-to-energy, compost reuse, and water recirculation loops
- Renewable energy through photovoltaic installations powering cold storage and digital classrooms
- Smart agricultural interfaces with sensors managing hydroponic irrigation and environmental conditions
- Community Wi-Fi and digital content hubs supporting technical training and outreach. Figure e.

E. Projected Impacts on Territory and Community

The Agri-Tech Community Center is conceived as a catalyst for sustainable local development, impacting six main domains:

➢ *Social and Educational Impact:*

Empowerment of youth and women through technical training and entrepreneurship; reduction of school dropout rates due to new apprenticeship pathways.

➢ *Economic Impact:*

Job creation in agriculture, processing, construction, and education sectors; increased household income via local value chains.

➢ *Environmental Impact:*

Lower carbon footprint through reduced food transportation; closed-loop waste and water management systems.

➢ *Spatial Impact:*

Revitalization of underused urban plots; a replicable model for upgrading peri-urban areas in secondary towns.

➢ *Technological Transfer:*

Dissemination of low-tech agricultural innovations to surrounding rural communities; community-led modular replication.

➢ *Governance and Participation:*

Proposal for community-based management; participatory design and prototyping workshops strengthening ownership.

Refer table 3.

V. CONCLUSION

This study demonstrates the pivotal role of architecture as a driver for sustainable urban food systems in the African context. Through a design-based research approach, the proposed Agri-Tech Community Centre in Yoko integrates modular and holonic architectural principles with ecological and social innovation, resulting in a flexible and context-responsive model for urban agriculture.

While promising, this model faces limitations related to economic evaluation, governance frameworks, and regulatory contexts, which require further exploration through pilot implementations and policy dialogue. Future research should also consider comparative studies across diverse African urban settings and investigate cooperative governance models to maximize social equity and sustainability.

Overall, the Agri-Tech Community Centre prototype contributes to rethinking architecture's mission in African cities, not merely as shelter or form but as an active mediator of ecological, social, and territorial transitions. This work opens avenues for architects, planners, and policymakers to collaborate in building more livable, productive, and just urban environments.

ACKNOWLEDGEMENTS

I would like to express my sincere gratitude to Chorus Architecture for the valuable technical assistance they provided throughout my research. Their support, insightful advice, and expertise have greatly contributed to the success of this work. I am deeply thankful for their availability and collaboration.

REFERENCES

[1]. *Défis alimentaires en Afrique: S'attaquer à la racine des problèmes*. (s. d.). [Text/HTML]. IFC. Consulté 13 juin 2025, à l'adresse https://www.ifc.org/fr/stories/2020/africa-food-security-fr
[2]. FICOU, M. (2025, mars 17). Comment promouvoir l'agriculture urbaine pour nourrir les villes africaines face à une urbanisation galopante ? *VivAfrik - Actualité*. https://www.vivafrik.com/2025/03/17/comment-promouvoir-lagriculture-urbaine-pour-nourrir-les-villes-africaines-face-a-une-urbanisation-galopante-a74511.html
[3]. Kamga, Y. B., Legwegoh, A., Riley, L., Lekeufack, M., & Njukeng, E. P. (s. d.). *SÉCURITÉ ALIMENTAIRE DANS LES VILLES SECONDAIRES EN AFRIQUE: N°. 3. DSCHANG, CAMEROUN.*
[4]. Rafiei, F. (s. d.). *L'intégration de l'agriculture urbaine à l'architecture pour la réalisation d'une ville viable.*

Table 1 Project application of 7-S analysis of Yoko's Territorial Potential

Pillar	Project application
Structure	Modular organization, spatial distribution in five interconnected zones.
System	Decentralized management of flows (water, energy, waste), community governance.
Strategy	Strengthening food self-sufficiency, knowledge transfer, local inclusion.
Style	Sober architectural language, inspired by the vernacular context and agro-ecological logics.
Staff	Involvement of local players: craftsmen, trainers, farmers, community leaders.
Skills	Skills transmitted through the project: agroecological cultivation, processing, management.
Shared values	Food security and self-sufficiency, solidarity, intergenerational transmission.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25aug359

Table 2 Functional Holons and Their Components

HOLONS	COMPONENTS
Production Holon	Pilot green house, Aquaponics, Hydroponics, Nursery, Composting
Transformation Holon	Shared kitchen, Solar dryer, Storage unit, Cold room, HACCP block, Delivery dock
Education Holon	Training room, Digital room, Agri-tech fablab, Media library, Sanitary facilities
Community Holon	Green agora, Open-air theater, Covered multi-purpose hall, Weekly market
Administrative Holon	Réception, Coordination office, Meeting room, Infirmary, Maintenance/logistics office
Technical Holon	Energy room, Water/filtration room, Maintenance workshop, Communal toilets
Circulation and transition	Patios, covered walkways, planted buffer zone

Table 3 Impact Assessment Grid by Domain

Criteria	Targets	Level of achievement (qualitative)
Integrated cultivable area	≥ 30% of available roofs and soils	Achieved (roofs + hanging gardens + greenhouses)
Production diversity	>10 edible species in seasonal rotation	Achieved (leaves, tubers, vegetables, fish)
Biomass recycling	≥ 70% of organic waste recovered	Under development (compost and biodigester)
Autonomous water management	≥ 50% of needs covered by recovery/treatment	Achieved (tanks, Phyto depuration)
Energy sovereignty	≥ 60% of energy produced on site	Partially achieved (solar + passive)

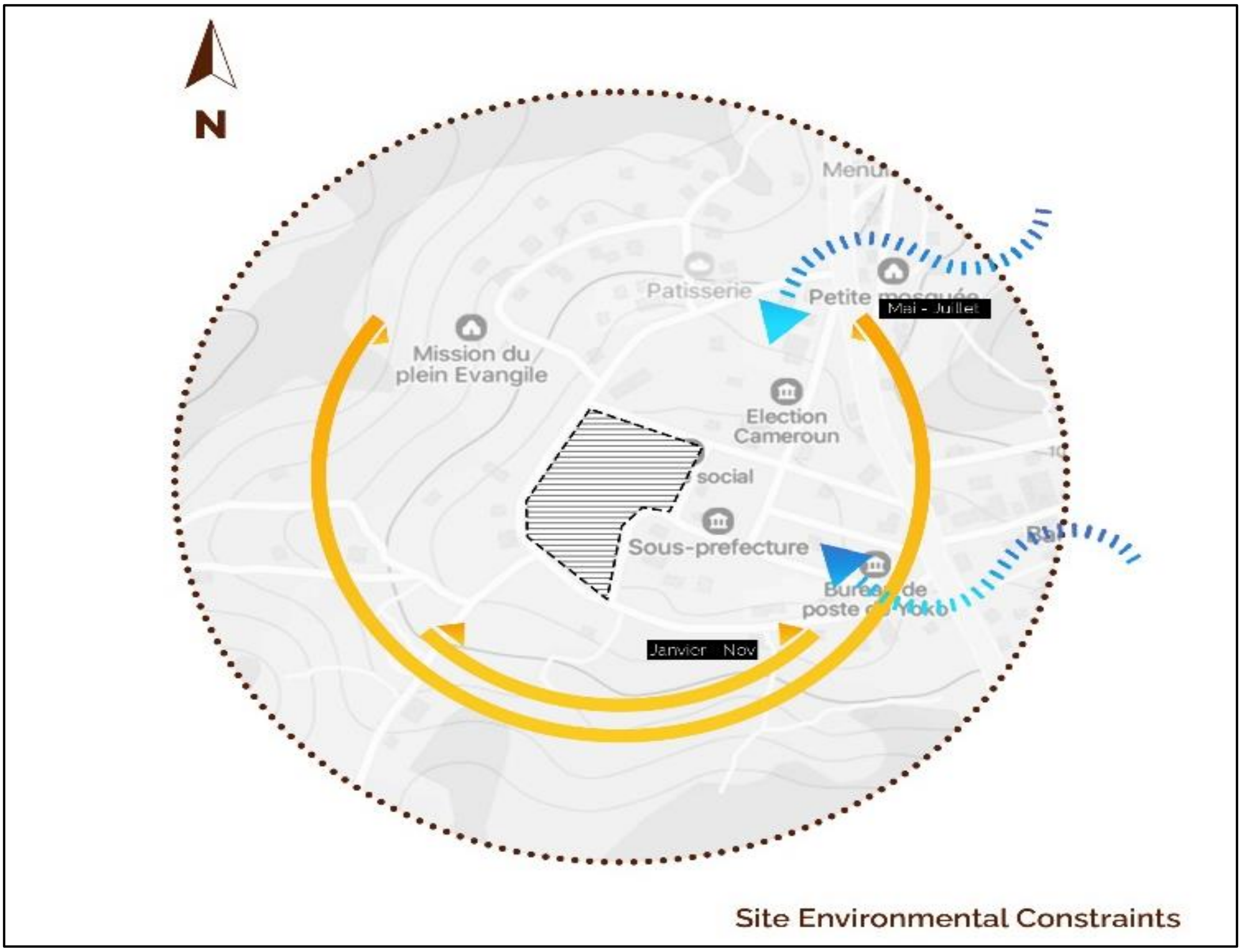

Fig 1Site Environmental Constraints

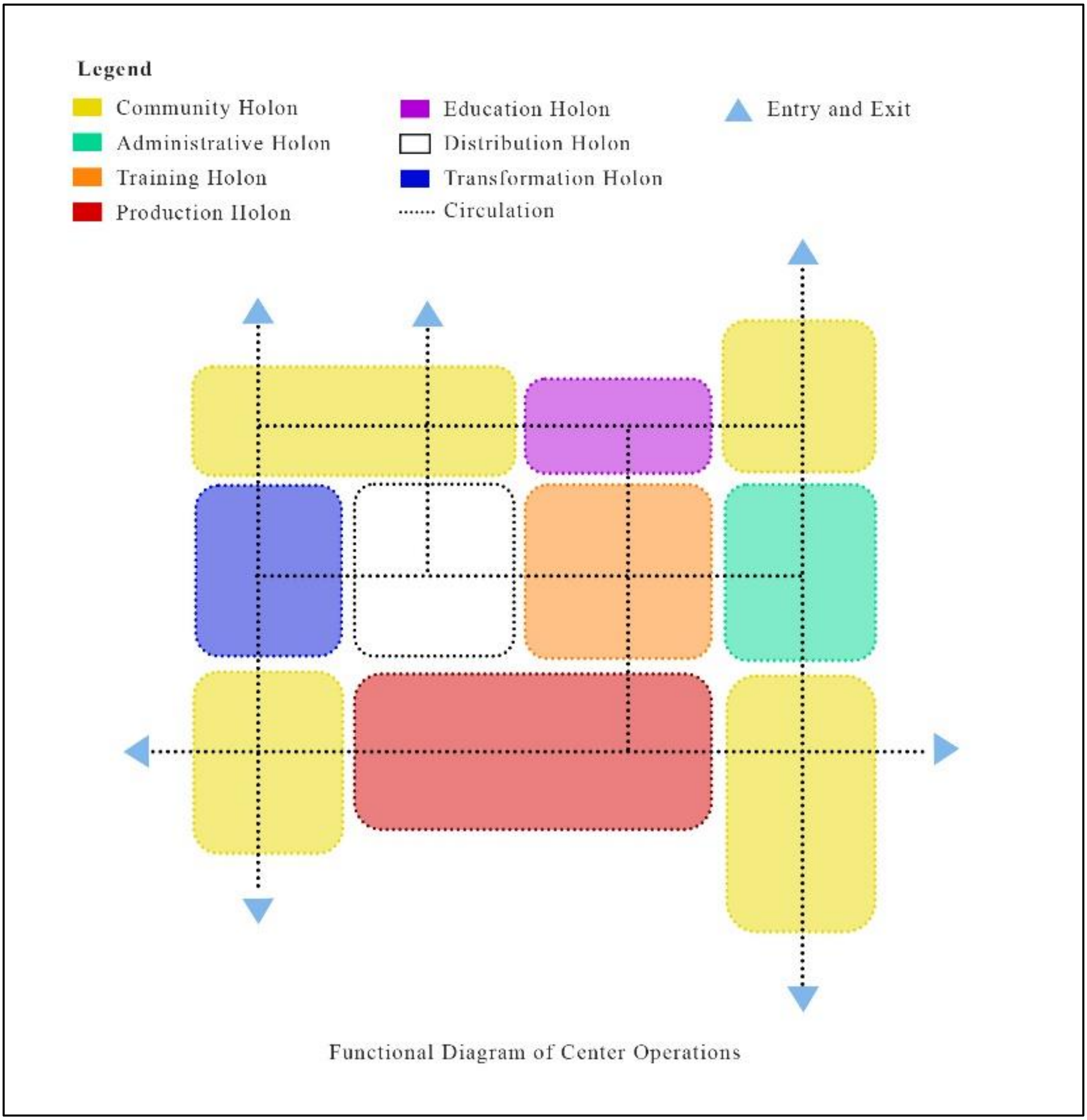

Fig 2 Functional Diagram of Center Operations

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25aug359

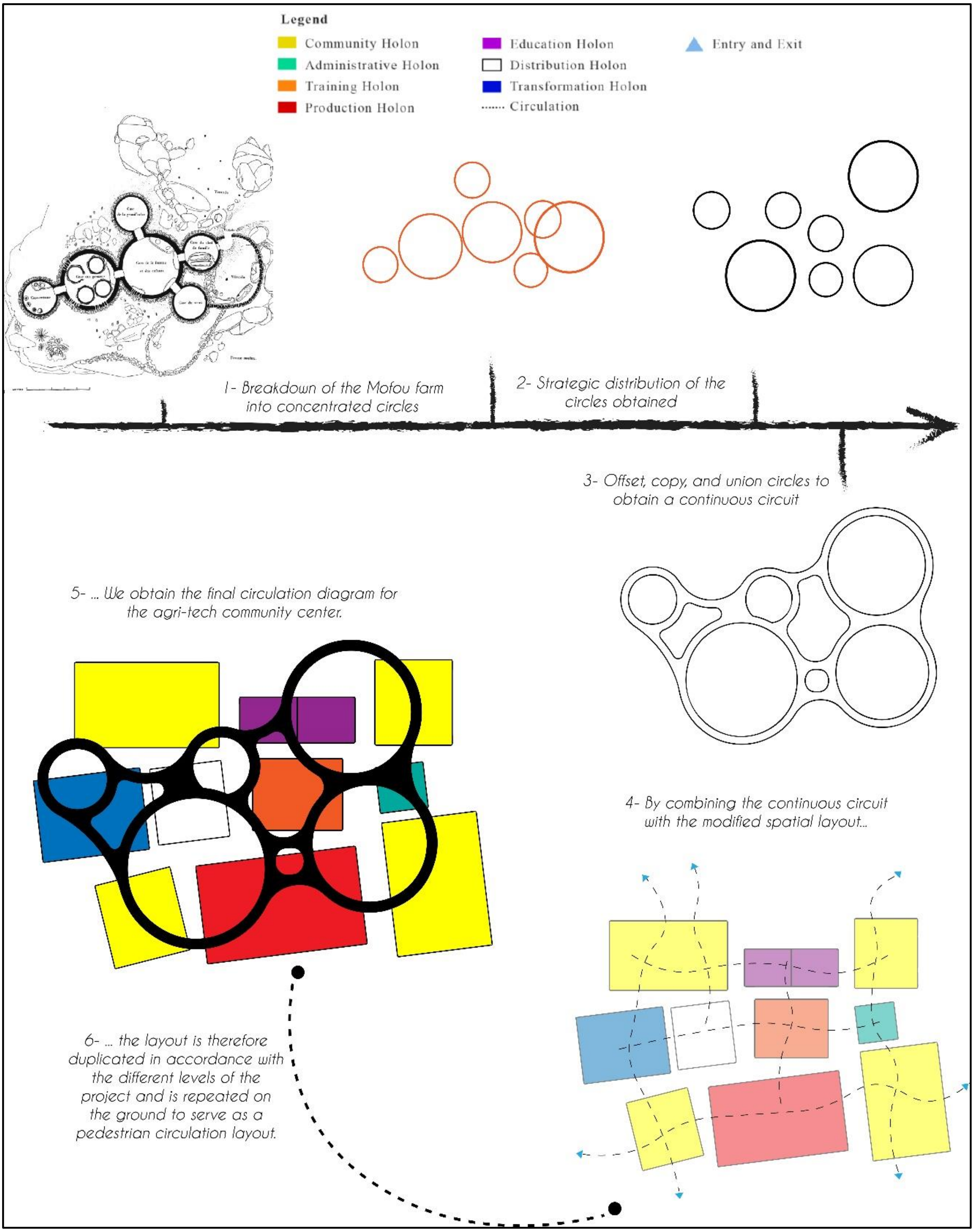

Fig 3 Holonic and Modular Layout

Fig 4 3D Architectural Model View

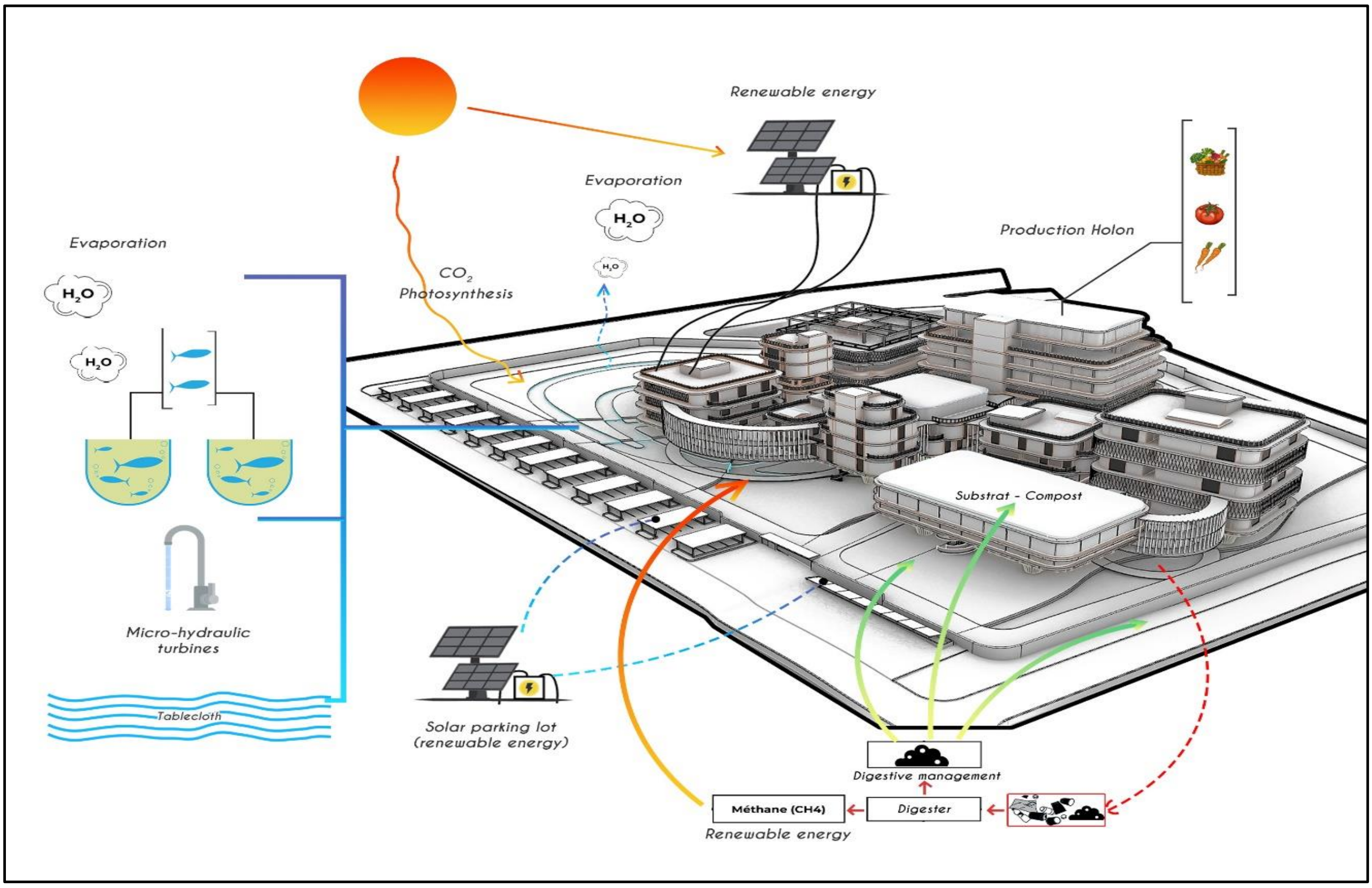

Fig 5 Integrated Resource Systems Diagram