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Suitability assessment and recommendations for Urban agricultural development: A case study in Cai Rang District, Can Tho City, Viet Nam

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Abstract

This study aimed to assess the contributing aspects and design decentralized adaptive models for urban agriculture. The research techniques included data collection, surveying and interviewing farmers, statistical analysis and FAO land suitability assessment techniques. The results show that the model of growing green vegetables, fruits and vegetables outside, together with decorative plants, orchids and raising cattle, is the most effective. Moreover, job-creating models boost income, calm down people, spread joy, supply clean food right away, provide room for greenery, recycle agricultural waste and reduce environmental pollution. The outcome is the foundation for selecting the best foreign investment model for future growth. According to the study's findings, sustainable agricultural options for the area assist people in living better, protecting the environment, and earning more money in the future.

Keywords

FAO, land use, land evaluation, MCE, sustainability

Introduction

According to one report, urban expansion in Asia is concentrated in metropolitan areas (1). As a result, it has adversely affected in-city food production by decreasing farmlands in and around urban centers. Moreover, agriculture is one of the most sensitive sectors in underdeveloped nations to climate change and water constraints (2). Therefore, urban agriculture produces, processes and distributes agricultural products in urban and suburban regions. Urban agriculture comprises of communal gardens, roofs, hydroponic, aeroponic and aquaponic facilities and vertical production models (3). According to one study area aims to shift the economic structure toward prioritizing industry, trade and services with rapid urbanization (4).

The study area is a city of industrialization, modernization and urbanization. It is one of the city's three central districts (5). On the contrary, the district organizes production and forms typical agricultural products, gradually affirming the quality and brand at home and abroad. Furthermore, in the context that the agricultural land area is shrinking, the urban area has actively restructured the agriculture industry towards increasing product value and sustainable development, focusing on reorganizing agricultural production. Therefore, develop the agricultural product processing industry based on the situation (6).

The study aims to identify the socio-economic and environmental factors in constructing and recommending urban agricultural models for local communities' social and economic development. Besides, it is also to assess the adaptability of models in the development of urban agriculture in the district, creating a basis for planning socio-economic development strategies, taking advantage of opportunities, and developing socio-economic development. Furthermore, it can contribute to urban green development and meet the demand for agricultural products in urban areas.

Materials and Methods

Data collection

Data collection: Get secondary information on the study area's changing land features. The situation of agricultural output, the state of land usage at the time, and the direction of socio-economic development in Cai Rang district and Can Tho city were all documented and gathered. Moreover, information on land resources, such as soil, water and climate, that impacted crops was gathered through participatory rural appraisal and published research.

The study was located in the Cai Rang district, which belongs to Can Tho City, Vietnam

Collecting relevant information at the units, production facilities, management agencies and specialists on:

Physical conditions: current land use status; advantages and disadvantages of cultivation and production techniques etc.

Economic conditions: productivity, investment costs, market potential, prices, labor days, levels of intensive farming practices, farming techniques, accessibility to science and technology, seasonality, credit, potential, difficulties and desires of people in production.

Social conditions: reports on results of land use planning, the master plan for socio-economic development of the study area, the consumption market, policies and welfare in the area research.

Farmers interviewing

Primary data collection: survey and interview households with 290 questionnaires to get information to assess people's socio-economic and environmental conditions when cultivating urban agriculture models. Current status of agricultural production in Cai Rang urban area: types of agriculture (households, small and medium-sized businesses, community gardens etc.), types of products produced and consumed (vegetables, tubers, fruit).

The positive and negative impacts of the model on the socio-economic and environmental contexts:

+ Economic indicators: productivity, investment costs, market potential, prices.

+ Social indicators: working days, levels of intensive farming, farming practices, techniques, accessibility to science and technology, seasonality, policies, potentials, difficulties, farmers' desires and people in production.

+ Environmental indicators: the impact of models on the ecological *environment.*

Sustainability assessment

Multi-objective assessment method through standardized scoring formulas built based on (7) land evaluation criteria and other studies and implemented in the Mekong Delta (6, 8).

The goal is to develop a model that fully meets all three criteria (9), including the economy (the method of rate transformation to reduce to the value 0-1), society and environment (determined by qualitative assessment methods).

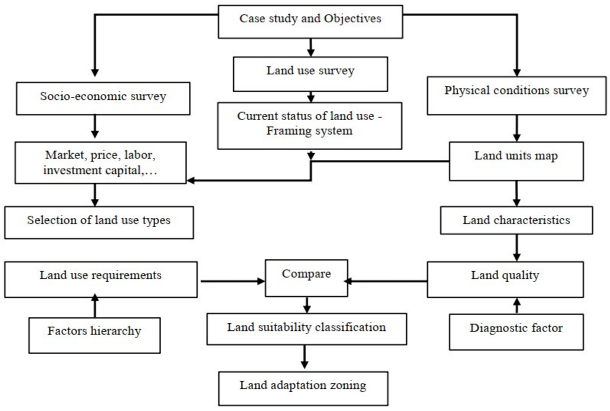

Fig. 1. Process of physical land evaluation (Source: FAO, 1976)

Determine the value of points using a 5-level rating scale and convert from qualitative to quantitative (8).

Raw point normalization: apply the normalization method of dividing by the maximum value to convert values to the same unit of measure in the range 0 → 1.

LUT factor score (j) (i) = (factor score (j) of LUT (i))/(factor (j) _max) (10).

In which:

The factor score (j) of the LUT (i) is the value of the

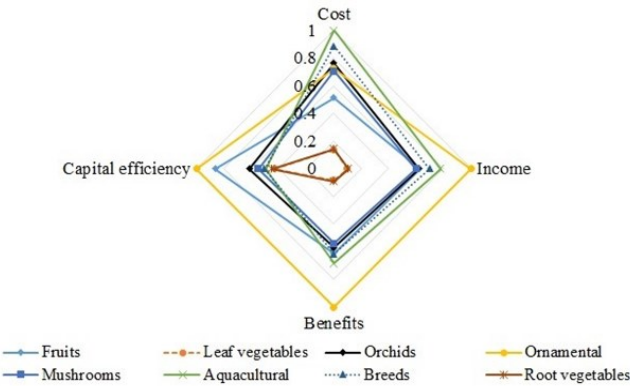

Fig. 2. Weight economy of urban agriculture models in Cai Rang district

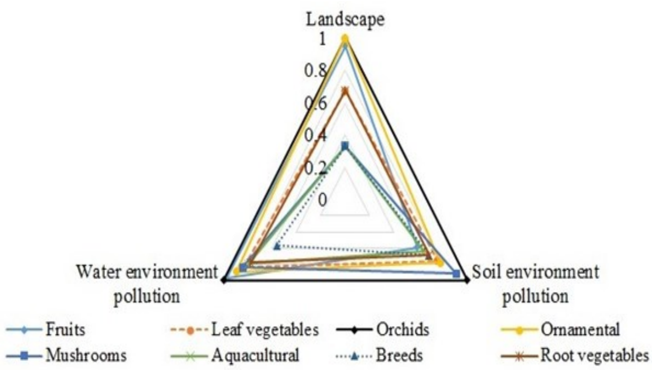

Fig. 3. Weight Environmentally of urban agriculture models in Cai Rang District

Table 5. Suitability classes of the orchid model according to socio-economic-environmental efficiency goals

Target	Diagnostic Requirements	Suitability			
		S_1	S_2	S_3	N
Nature	Location	Garden	Terrace	-	-
	Water supply capacity	Automatic	Handmade	-	-
	The ability to hold water	Good	Medium	Least	-
Economy	Total revenue (million/year/1000 pots)	>160	80 - 160	40 - 80	<40
	Cost (million/year/1000 pots)	>80	40 - 80	20 - 40	<20
	Profit (million/year/1000 pots)	>80	40 - 80	20 - 40	<20
Society	Labor (person)	>2	1-2	1	-
	Time of care (h/day)	>2	twelfth	0.5 – 1	<0.5
Environment	Pollution of soil, water, air	No	No	Yes	Yes
	Beautify the landscape	Yes	Yes	-	-

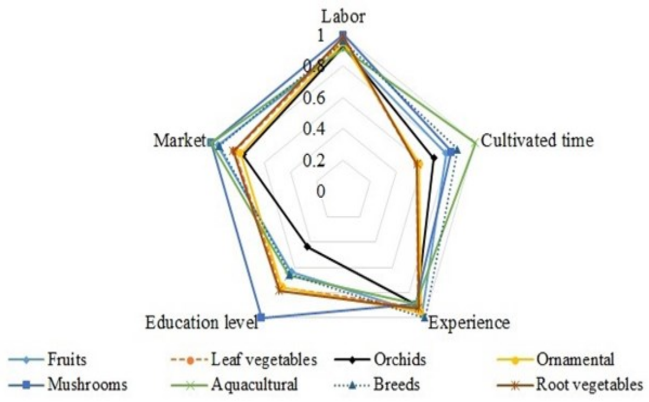

Fig. 4. Weight Sociality of urban agriculture models in Cai Rang District

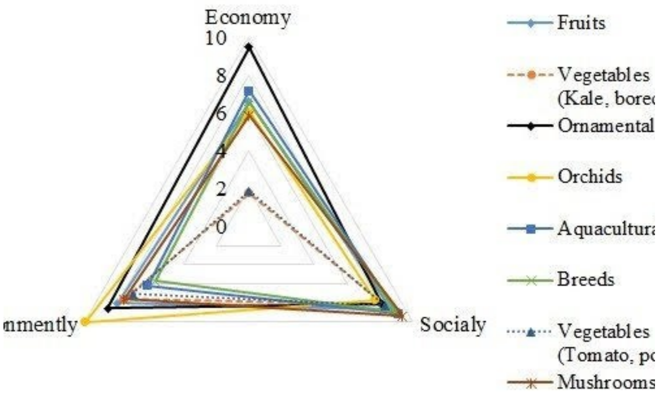

Fig. 5. Overall weight for 3 factors for urban agriculture models in Cai Rang district

selection factor (1 out of 3 sub-objectives) of the LUT (i) converted from qualitative to quantitative.

Factor (j)_max: the highest value of the selection factor in all land use types.

Wi = Xi. E(j) (3)

Where: Wi is the i-th target evaluation score. Then, the combined efficiency score of all targets in the farming model is represented by a radar (kite) chart. Proposed order of priority of land use types.

The combined effect score is calculated according to a formula based on the weighted and standardized scores of the economic (Fig. 2) and environmental (Fig. 3), social (Fig. 4), overall objectives (Fig. 5 and Table 5).

Suitability assessment for recommended models

The land suitability assessment method (Fig. 1) of (11) was applied to classify adaptation factors based on % of the optimal yield of each urban agricultural model of the district. From the results of economic analysis, average the

Table 1. Land suitability classes of leafy vegetables and fruits according to the goal of natural efficiency

Factors	Diagnosis requirements	Suitability			
		S_1	S_2	S_3	N
Nature	Location	Garden soil	Around the house	-	-
	Occurence of acid sulfate horizon (cm)	alluvial	50-80	80-120	-
	Flood depth (cm)	<40	40-60	60-80	>80
	Topsoil Soil texture	silty sand, silt, silty clay	Silty clay, clay	-	-
	Water supply capacity	actively pump irrigation, pump 2 months	Pump 2.5 - 3 months	-	-
Environment	Pollution of soil, water, air	No	low	Medium	high

lower threshold of the factor hierarchical as follows: S_1: Highly adaptive; S_2: Moderately adaptive; S_3: Poor adaptation; N: Not adapted. In which: S_1> 80%; S_2: 40% - 80%; S_3: 20% - 40% and N<20% for all models (Table 1).

Results

Sustainability Assessment of urban agricultural models

The results of the household socio-economic survey are based on the current land use status combined with the local development orientation and the ecological requirements of the land use types.

There are eight farming models selected to evaluate their effectiveness, including the model of fruit trees (grapefruit, oranges, mangoes, seedless lemons, jackfruits, milkweeds and coconuts), ornamental models (plums, porcelains, chrysanthemums, marigolds, roses, paper flowers), vegetable models of leafy foods (collot, kale, lettuce, coriander, laksa leaves, herbs and mint) and livestock models. Mushroom Model (Red Ganoderma, Abalone Mushroom), Orchid (Orchidaceae) Model Diep (Phalaenopsis), Lan Ngoc Diem (Rhynchostylis), Lan Vu Nu (Oncidium Arachnis annamensis), Fishery Models (Red Tilapia, Crispy Carp, Giant Carp, Ornamental Fish, Pangasius, Catfish, Snakehead, Tilapia), Breeding Models (French Beef, Beef, Buffalo, Wild Boar, Chicken, Duck, Ornamental Bird), Vegetable Models (Tapio, Peanuts, Green Beans, Chickpeas, Okra, Bitter Melon, Tomato).

Level 1 criteria: by implementing overlapping charts to evaluate the effectiveness of the level 1 indicator of all models, we can compare the sustainability of all three economic, social and environmental conditions of the models together, from which to choose the model that has the potential to ensure effective development.

The analysis of the level 1 criteria shows that the model achieves balance and is optimal among all 3 objectives, which is the Ornamental model. However, the remaining models only guarantee some goals, which achieved this goal but were poor in the others. For example, the model of orchids, mushrooms, fruits, leafy vegetables, and vegetables has guaranteed social and environmental goals but average economic goals. On the other hand, the Fishery and Livestock model has a better economic objective than other models, achieving the social goal well but the environmental goal the worst.

Level 2nd criteria: In the economic goal of all the applied models, it is found that no model achieves a high-efficiency level for the economic objective. Each model has its shortcomings. Clearly showing the mushroom model, the indicators of total expenditure, income and profit are all very high, but capital efficiency is average. The fruit tree and livestock and fisheries production models are the most effective models because the investment costs are low. Still, the profits are pretty high and the capital efficiency is high.

On the other hand, the model of leafy vegetables and orchids achieves high capital efficiency when other criteria are pretty low. The overview of social goals for the models shows that the model reaches a balanced level in all secondary indicators, namely the Fisheries and Fruits models. The Livestock model is relatively high. Ornamentals, leafy vegetables and orchids achieved efficiency in the model's implementation criteria of experience, market and labor. The mushroom model is adequate for most requirements except for implementation because it is a new model that has yet to be expanded in the region. Orchid is the most effective model regarding set goals, balance and efficiency regarding environmental indicators. The Fruit, Aquatic and Vegetable model strongly impact soil and water environments.

The model of orchids, mushrooms, fruit trees, leafy vegetables and vegetables needs economic improvement measures such as training on transferring farming techniques to farmers according to safe production standards and applying high technology oriented towards the GAP process. To build specialized production areas, register quality standards and have trademarks. Developing closed production types and linking between stages in the production chain The aquaculture and animal husbandry model impacts the environment. Applying environmentally friendly technical advances such as composting using natural mulch and water treatment is recommended in implementing the model. Waste by aquatic plants, re-planning the system of barns. For aquaculture, it is necessary to focus on managing the water quality of aquaculture ponds and developing farming models associated with environmental protection. The appropriate technology models of aquaculture waste treatment are recommended to meet environmental standards, such as sludge treatment, wastewater treatment and disinfection before discharge. Focus on thorough waste treatment in models of intensive farming, industrial farming, raft farming on rivers and canals and integrated pest management in aquaculture.

Suitability assessment for urban agricultural model

Table 2. Suitability classes of vegetables on the land according to socio-economic efficiency factors

Factors	Diagnostics requirements	Soil suitability classes for vegetables				Soil Suitability classes for fruits			
		S_1	S_2	S_3	N	S_1	S_2	S_3	N
Economy	Total revenue (million/ year/0.1ha)	>7.2	3.6-7.2	1.8-3.6	<1.8	>6	3-6	1.5–3	<1.5
	Cost (million/year/0.1ha)	>3.2	1.6-3.2	0.8-1.6	<0.8	>2.4	1.2–2.4	0.6-1.2	<0.6
	Profit (million/year/0.1ha)	>4	2–4	1-2	<1	>3.6	1.8–3.6	0.9-1.8	<0.9
Society	Labor (person)	>3	2-3	1-2	-	>3	2-3	1-2	-
	Time of care (h/day)	>4	2-4	1.5-2	<1.5	>3	2-3	1-2	<1

The survey results showed that 289 households practiced urban agriculture in the study area. The method of the FAO's land suitability assessment (6) study presents the suitability classification of some agricultural models as being more effective in terms of economy, society and environment than other models, specifically as follows:

The adaptive characteristics of the leafy vegetable cultivation model and vegetables and fruits grown directly on the soil compared with the natural properties, socio-economic conditions and environment show that the model has good applicability in the Cai Rang district. Specifically, in Tables 1 and 2 leafy vegetables are adapted.

Highly suitability (S_1): to the area with natural environmental conditions of garden soil: no alum <40 cm; silty sand; silty clay; actively pumping for irrigation, pumping for 2 months; no pollution. Economic and social conditions with total revenue >7.2 million/year/0.1ha, costs >3.2 million/year/0.1ha, profit >4 million/year/0.1ha and labor Working > 3 people, taking care of > 4 h/day.

Moderate suitability (S_2): to the area with natural and environmental conditions: planting location around the house, acid sulfate soil depth of 50-80 cm, flooding depth of 40-60 cm, mixed clay, clay; pumping 2.5-3 months; low pollution. Economic and social conditions with total revenue of 3.6-7.2 million/year/0.1 ha, cost of 1.6-3.2 million/year/0.1 ha, profit of 2-4 million/year/0.1ha, 2-3 people, and 2-4 hrs of care per day.

Marginal suitability (S_3): to areas with natural and environmental conditions: alum depths of 80-120 cm, flooding depths of 60-80 cm, medium pollution. Economic and social conditions with total revenue of 1.8-3.6 million/year/0.1ha, cost of 0.8-1.6 million/year/0.1ha, profit of 1-2 million/year/0.1ha, 1-2 people's labor, 1.5-2 hrs of care (h/day).

Unsuitability (N): to areas with flood depths >80 cm and highly polluted environments.

However, Table 2 shows that vegetables and fruits on land have lower socio-economic adaptability than leafy vegetables grown directly on the land. Specifically: high adaptability (S_1) with total revenue >6 million/year/0.1ha, cost >2, 4 million/year/0.1ha, profit >3,6 million/year/0.1ha, labor >3 people and a long time to take care > 3h/day. Medium adaptation (S_2) with total revenue of 3–6 million/year/0.1ha, cost 1.2-2.4 million/year/0.1ha, profit 1.8-3.6 million/year/0.1ha, 2-3 people, and 2-3 hrs of care per day. Poor adaptation (S_3) with total revenue of 1.5-3 million/year/0.1ha, cost 0.6-1.2 million/year/0.1ha, profit 0.9-1, 8 million/year/0.1ha, 1-2 people laborer, 1-2 hrs of care per day. Unadapted (N) with total revenue <1.5 million/year/0.1ha, cost <0.6 million/year/0.1ha, profit <0.9 million/year/0.1ha, duration care time <1 h/day. It shows that the model has a lower total revenue, cost, profit and care time requirement than leafy vegetables grown on land.

Table 3 shows that breeding is a widely distributed model in the district due to its suitable terrain and climate for raising cattle and poultry. In addition, there are models of ducks, wild boars and ornamental birds. The selection of beef cattle and chicken models to analyze for environmental goals includes using agricultural waste, causing pollution and spreading diseases.

The model of highly adaptable beef cattle (S_1) in the economy has a total revenue of >48 million per year per 100 heads, a cost of >32 million per year per 100 heads, and a profit of >16 million per year per 100 heads. On the other hand, the model of domestic chickens with medium adaptation (S_2) to the economy has a total revenue of >24 million per year per 100 heads, a cost of >19.2 million per year per 100 heads, and a profit of >4.8 million per year per 100 chickens.

Table 4 shows that the high adaptability requirements of the ornamental plant model compared to the characteristics and current status of the study area make it suitable to apply the model. Decorative models are widely distributed in all regions and adapted to many

Table 3. Suitability classes of livestock models according to socio-economic efficiency goals

Factors	Diagnosis requirement	Suitability			
		S1	S2	S3	N
Economy (million/year/100 head)	Total revenue of beef cattle	>48	24 - 48	12 - 24	<12
	Cost of beef cattle	>32	16 - 32	8 - 16	<8
	Beef cattle profit	>16	8 - 16	4 - 8	<4
	Total revenue of chickens	>24	12 - 24	6 - 12	<6
	Chicken cost	>19.2	9.6 - 19.2	4.8 - 9.6	<4.8
	Chicken profit	>4.8	2.4 - 4.8	1.6 - 2.4	<1.6
Society	Labor (person)	>3	2 - 3	1-2	-
	Time of care (h/day)	>4	2 - 4	1-2	<1
Environment	Agricultural waste	Yes	Yes	No	No
	Pollute	No	No	Yes	Yes
	Pandemic	No	No	Yes	Yes

Table 4. Suitability classes of ornamental plants according to socio-economic efficiency goals

Factors	Diagnosis requirements	Suitability			
		S_1	S_2	S_3	N
Nature	Location	Garden	Around the house	Terrace	-
	Water supply capacity	Automatic	Handmade	-	-
Economy	Total revenue (million/year/1000 pots)	>80	40 - 80	20 - 40	<20
	Cost (million/year/1000 pots)	>32	16 - 32	8 - 16	<8
	Profit (million/year/1000 pots)	>48	24 - 48	12 - 24	<12
Society	Labor (person)	>3	2 - 3	12	-
	Time of care (h/day)	>4	2 - 4	12	<1
Environment	Create green space	Yes	Yes		-
	Pollution of soil, water, air	No	Low	Medium	High

conditions.

With the area's natural characteristics, the orchid model can adapt well and is suitable for the model to continue to develop (Table 5).

Discussion

The development orientation of the district in the coming time is to focus on areas specialized in vegetables, flowers, high-end flowers and bonsai with high economic value, motivating other sectors to develop. For the vegetable area, the district will focus on planning the development of production in the direction of goods attached to eco-tourism services; develop the production of eaten mushrooms and medicinal mushrooms by applying technology to production and processing to increase the value of fungi. The district needs to develop a long-term urban agricultural development strategy following the urban development planning in the district, functional boundaries for agricultural production land and technical infrastructure system planning to support urban agriculture development. Mobilize and make the most of the urban spaces for agricultural production to increase economic efficiency and provide a green living environment for urban people (12).

For the Cai Rang district, ornamental plants, abalone mushroom cultivation and hydroponic vegetables are crops with great potential for growth in the context of increasingly modern agriculture. Therefore, partitions favor naturally adaptable models following selection criteria and hierarchies tailored to models based on development orientation, intending to plan and reorganize production and the sustainable development of models. It will satisfy the needs of a future strategically oriented development of the Cai Rang district in conjunction with planning and reorganizing production for production models not directly impacted by natural factors.

According to one report, urban agriculture has become a significant part of the local food system and economy (1). Numerous advantages have been attributed to it, including increased urban food and vegetable production, primary or secondary income for farmers and a means of reducing environmental pollution by increasing "green" cover, among many others. However, prospective or even established farmers frequently face difficulties with high financial and infrastructural requirements to start up, operate and maintain urban agriculture ventures. In addition, space restrictions often lead to zoning laws that could restrict urban agriculture activities in densely populated urban areas. Despite these constraints, urban agriculture has successfully increased the quantity of food and vegetables available to city dwellers (13).

The model of orchids, mushrooms, fruit trees and leafy and root vegetables needs economic improvement measures such as training on transferring farming techniques to farmers according to safe production standards and applying high technology oriented towards the GAP process. To build specialized production areas, register quality standards and have trademarks. Developing closed production types and linking between stages in the production chain The aquaculture and animal husbandry model impacts the environment. In implementing the model, it is recommended to apply for environmentally friendly technical advances, such as composting using natural mulch and water treatment. Waste by aquatic plants, re-planning the system of barns. For aquaculture, it is necessary to focus on managing the water quality of aquaculture ponds and developing

Table 6. Summary of sustainability assessment on 6 promising models

	Fruits	Leaf vegetables	Ornamental	Orchids	Aqua-cultural	Breeds	Root vegetables	Mushrooms
Economy	0.66	0.18	0.95	0.61	0.72	0.66	0.19	0.59
Social	0.87	0.82	0.81	0.77	0.91	0.9	0.83	0.94
Environment	0.8	0.76	0.86	1	0.62	0.57	0.71	0.76

farming models associated with environmental protection. The ornamental model meets all three economic, social and environmental goals. The models of orchids, mushrooms, fruits, leafy vegetables and vegetables have guaranteed social and environmental goals but average economic goals. The Fishery and Livestock model has a better economic objective than other models, achieving the social goal well but the environmental goal the worst. To develop sustainability for urban agriculture, it needs to have a planning direction and orient the consumption market, aiming to increase economic and social efficiency for the people. Models with substantial environmental impacts should pay special attention to environmental protection criteria and urban ecosystems. In particular, given the difficulties of each model, it is necessary to improve the efficiency and development ability to turn urban agriculture into a new and sustainable direction for the locality (15, 16).

Conclusion

The results of the study have found sustainable agricultural models for the district, which contribute to improving the quality of life, protecting the environment and increasing the income of people in the future. The economy of our nation is heavily reliant on agricultural produce. Therefore, urban agriculture is becoming increasingly crucial as urbanization reduces agricultural land availability. The study's findings indicate that the farming practices and scope of the urban agriculture system in the Cai Rang district are very varied. The three components of the agricultural framework are agriculture, livestock and fisheries. The urban agriculture models in the Cai Rang district are generally adapted to the district's natural, socio-economic and environmental conditions, are initially effective and are capable of replication and development. The most effective are the models of leafy vegetables, vegetables and fruits on the land, ornamental plants, orchids and cattle raising. Social: create jobs, increase income, relax, create fun and provide clean food on the spot. About the environment: create green space, use agricultural wastes and limit pollution.

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Authors contributions

PTV carried out field data collection and experiments. VQM conceived of the study and participated in its design and coordination and performed the statistics.

Compliance with ethical standards

Conflict of interest: The authors do not have any conflict of interest to declare.

Ethical issues: None.

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