

A Critical Review of Vermi-Composting in Urban and Peri-Urban Waste Management Apropos Robust Environment

Jayashree Dey Sarkar¹, Amrita Kumar Sarkar² and Sudhanand Prasad Lal³

ABSTRACT

Ever-increasing population growth, urbanization, and changing consumption patterns have led to an explosion in the amount of waste produced, especially in urban and peri-urban areas. Though urban organic waste contains relevant nutrients and organic matter, only 4% of global urban nitrogen (N) and phosphorus (P) sources are presently recycled. Through the vermicomposting process, using earthworms, organic wastes can be transformed into nutrient-enriched compost named vermicompost. Vermicomposting of urban waste, before land application, may be a sustainable waste management option, as the vermicast obtained at the end of the vermicomposting process is rich in plant nutrients and is free from pathogenic organisms. The vermicompost produced is both high in organic carbon (18.83-36.01%) and a potential fertilizer (1.16-2.58% N, 0.42-1.12% P, and 0.61-2.05% K). The nutrient profile in vermicompost is higher than traditional compost. It enhances soil fertility chemically, physically, and biologically. Vermicompost should be applied in moderate concentration to get maximum yield as high concentration application may impede growth due to the presence of a high concentration of soluble salt in vermicompost. The utilization of vermicompost produced from urban and peri-urban waste in agriculture will facilitate the growth of countries' economies by lowering the consumption of inorganic fertilizers and avoiding the land degradation problem.

Keywords: Earthworm, Waste Management, Urban Agriculture, Peri-Urban Agriculture, Vermicomposting, Solid Waste.

Introduction

Presently, solid waste management has become a worldwide concern. Day by day it is becoming more problematic due to rise in population, industrialization as well as changes in our lifestyle. The uncontrolled misuse of abundant

-
1. Research Scholar, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia, West Bengal
 2. Ph.D. Scholar, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia, West Bengal
 3. Assistant Professor cum Scientist, Dr. Rajendra Prasad Central Agricultural University, Pusa, Samastipur, Bihar- 848125, India
Corresponding Author Email: deysarkarjayashree1@gmail.com

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resources has finally resulted in generation of a huge quantity of complex solid waste. Most of the waste generated is either disposed of in an open dump in developing countries or landfills in the developed ones. Landfilling as well as open dumping requires lot of land mass and could also result in several environmental problems. Waste management practices are necessary to keep the environment clean and green. Land application of urban/municipal solid waste (MSW) can be carried out as it is rich in organic matter and contains significant amount of recyclable plant nutrients. The presence of heavy metals and different toxic substances restricts its land use without processing (Singh et al., 2011). Vermicomposting of MSW, before land application may be a sustainable waste management option, as the vermicast obtained at the end of vermicomposting process is rich in plant nutrients and is devoid of pathogenic organisms (Suther, 2010). Utilization of vermicast produced from urban/municipal solid waste in agriculture will facilitate in growth of countries economy by lowering the consumption of inorganic fertilizer and avoiding land degradation problems. Urban/Municipal Solid Waste (MSW) is usually regarded as the waste that is generated from human settlements, small industries, commercial and municipal activities. Vermicomposting of urban/MSW can be an excellent practice, as it will help recycle valuable plant nutrients.

Vermicomposting as a way of Urban Solid Waste Management

Vermicomposting is a non-thermophilic process in which with a joint action of earthworms and mesophilic microorganisms organic wastes convert into a nutrient rich valuable end product called vermicompost (Bhat et al., 2017). Soil earthworms play crucial role in agriculture. They decompose dead organic litter by consuming it and releasing it as castings (Ali et al., 2021). The earthworms accelerate decomposition of plant litter and organic matter and improve soil fertility by releasing mineral elements in forms that are easily uptake by plants (Edwards, 1998). Although microorganisms are responsible for the biochemical degradation of organic matter, earthworms are crucial drivers of the process (Dominguez and Edwards, 2004). They by fragmenting and conditioning the substrate, alter its biological activity. In the vermicomposting process the earthworms aerate, fragment the substrate and thus it increases the surface area for microbes and modifies the microbial activity in organic waste residues for decomposition (Bhat et al., 2018). Vermiculture is a cost-effective tool for environmentally sound waste management (Pathma and Sakthivel, 2012).

Production Phase

The vermicomposting process different phases during the process are as follows (Garg, Gupta, 2009): (1) Initial pre-composting phase: The organic waste is pre-composted for about 15 days before being fed to earthworms. During this phase,

readily decomposable compounds are degraded and the potential volatile substances are eliminated which may be toxic to earthworms. (2) Mesophilic phase: During this phase, earthworms, through their characteristic functions of breaking up organic matter, combine it with the soil particles enhance microbial activities and condition organic waste materials for the formation of organic manures. (3) Maturing and stabilization phase (Olle, 2019)

Raw Material for Vermicomposting

Cattle dung or farm yard manure (FYM) is used as raw material for vermicomposting, beside that any material that can be decomposed easily such as weeds, wastes (leaves and rind) of vegetables and fruits, crop residue, roughage of the animals as well as municipal wastes of organic origin could also be utilized for vermicompost preparation. The organic waste consumed by earthworms undergoes physical breakdown in the gizzard, which is then exposed to various enzymes such as protease, cellulose, lipase, chitinase, amylase, etc. secreted into lumen by the gut wall and associated microbes. the above enzymes cause breakdown of complex biomolecules into simple ones. Mucus secretions of gut wall provide structural stability of vermicompost. Only 5-10% of the ingested material is absorbed by earthworms for their growth and remaining is excreted as casting (Kumar et al, 2018) and by comminuting the organic matter they modify its physical and chemical status, gradually reducing its C:N ratio, increasing the surface area exposed to micro-organisms and making it much more favourable for microbial activity and further decomposition (Dominguez and Edwards, 2004). The behavioural activity of earthworms that are feeding, burrowing and casting, modify the physical, chemical and biological properties of organic matter and soil for plant growth and nutrient acquisition (Joshi et al., 2015).

Effect of Vermicompost on Agricultural Crop Performance

A. Yield: Studies on the production of important vegetable crops like eggplant (*Solanum melongena*), tomato (*Lycopersicon esculentum*) have yielded very good results. Vermicast produced higher garden pea green pod plants, higher green grain weight per plant, and higher green pod yield as compared to chemical fertilizer (Adhikary, 2012). The perusal of the data revealed that "Parthenium Vermicompost" applied at 5 t/ha enhanced the yield of eggplants (*Solanum melongena*). The use of vermicompost as a source of organic manure in supplementing chemical fertilizer is becoming popular among the farmers of the country. Vermicompost increases in crop yield probably because of higher nutrient uptake (Seethalakshmi, 2011).

B. Growth: Worms and vermicompost promoted excellent growth in the vegetable crop with more flowers and fruits development. Vermicompost can

have dramatic effects on the germination, growth, flowering, fruiting and yields of crops (Mistry, 2015). Vermicompost stimulated growth of tomato transplants, with up to a 2.2-fold increase occurring in shoot biomass. Differences in growth were attributed mainly to differences in nutrient content of the potting mixtures, but some changes in physical and biological properties of the substrate could also be responsible (Tringovska, Dintcheva, 2012). Application of vermicompost increased seed germination, stem height, number of leaves, leaf area, leaf dry weight, root length, root number, total yield, number of fruits/plants (Joshi et al., 2015). (Table 1)

Table 1: List of parameters of various plants enhanced by vermicompost application

Sl.No.	Crops	Parameter enhanced	Reference
1	Wheat (Triticum aestivum)	Mean plant height mean stem-diameter, number of leaves per plant, number of spikes/plant, spike length/plant, number of spikelets/spikes per plant, yield/acre, protein content, fat content, carbohydrate content, dietary fibers content, ash content Moisture content	Joshi et al. (2015)
2	Potato (Solanum tuberosum)	Net yield	Bhattacharya et al. (2012)
3	Maize (Zea mays)	Number of leaves, plant height, stem diameter, root volume, Mycorrhizal colonization, P content in leaves	Gutiérrez-Miceli et al. (2008)
4	Groundnut (Arachis hypogaea)	Number of leaves, leaf area, plant weight, plant dry weight, root length, shoot length, N content, Mg content, Ca content, K content, P content, no. of seeds/plant	Mycin et al. (2010)

5	French bean (Phaseolus vulgaris)	Germination, height of plant, number of leaves per plant, length of leaves, width of leaves, number of pods per plant, length of root, number of nodules, above ground dry plant biomass, below ground dry plant biomass, yield per plot, number of seeds per pod	Singh and Chauhan (2009)
6	Mustard (Brassica)	Leaf area, leaf area ratio, Crop growth rate, net assimilation, harvest index	Banerjee et al. (2012)
7	Pea (Pisum sativum)	Number of leaves, root weight, root length	Khan and Ishaq (2011)
8	Marigold (Tagetes)	Plant weight, plant dry weight, P content, flower yield, number of flowers	Paul and Bhattacharaya (2012)

C. Nutrient content: Vermicast produced higher percentage of protein content and carbohydrates in garden pea as compared to chemical fertilizer. Application of vermicompost increased chlorophyll content, pH of juice, total soluble solids of juice, micro and macronutrients, carbohydrate (%) and protein (%) content and improved the quality of the fruits and seeds. Studies suggested that treatments of humic acids, plant growth promoting bacteria and vermicomposts could be used for a sustainable agriculture discouraging the use of chemical fertilizers (Joshi et al., 2015). Comparison of nutrient content of vermicompost and farm yard manure is given in Table 2.

Table 2: Comparison of nutrient content of vermicompost, FYM

Parameters	Farmyard manure	Vermicompost
pH	7.81 ± 0.01	7.82 ± 0.04
Organic matter (g/kg)	461.2 ± 1.31	495.5 ± 2.7
Total C (g/kg)	266.3 ± 0.51	286.5 ± 1.67
Exch. C/N ratio	18.5 ± 0.13	12.3 ± 0.13
Total N (g/kg)	14.4 ± 0.31	23.1 ± 1.0
Avail. P (g/kg)	6.59 ± 0.03	9.85 ± 0.10
Exch. K (g/kg)	8.87 ± 0.05	15.2 ± 0.19
Exch. Na (g/kg)	5.70 ± 0.01	6.03 ± 0.06

Exch. Mg (g/kg)	2.59 ± 0.06	6.74 ± 0.10
Exch. Ca (g/kg)	15.7 ± 1.31	23.8 ± 2.91
Ext Fe (g/kg)	5.59 ± 0.121	8.68 ± 0.14
Exch Cu (g/kg)	0.77 ± 0.01	0.97 ± 0.04
Ext Zn (g/kg)	8.31 ± 0.10	16.9 ± 0.17
Ext Mn (g/kg)	7.72 ± 0.12	13.6 ± 0.18

Source: Suthar 2010

d. Plant protection: The most significant observation was drastically lower incidence of diseases in worm and vermicompost applied plant (Table 3). Accordingly, vermicompost also protects plants against various pests and diseases either by suppressing or repelling them or by inducing biological resistance in plants (Sinha et al., 2013; Dunn, 2011).

Table 3: List of different pests/ pathogens controlled through vermicompost application in different crops

S.no	Crops	Pest/pathogen	Reference
1	Corn (Zea mays) plant	Earworm (Helicoverpa zea)	Cardoza and Buhler (2012), Joshi et al., 2014
2	Mustard (Brassica Juncea) plant	Aphid (Lipaphis erysimi)	Nath and Singh (2011)
3	Cabbage (Brassica oleracea)	Earworm (Helicoverpa zea)	Little and Cardoza (2w011)
4	Tomato (Lycopersicum esculentum) and cucumber (Cucumis sativus) plants	Green peach aphid, citrus mealybug and two spotted mites	Edwards et al. (2010a)
5	Cucumber (Cucumis sativus) and Tomato (Lycopersicum esculentum)	Beetles and hornworms	Edwards et al. (2010b)
6	Brinjal (Solanum melongena)	Meloidogyne incognita	Nath et al. (2011)

e. Human health: Organically grown fruits and vegetables especially on earthworms and vermicompost have been found to be highly nutritious, rich in proteins, minerals and vitamins and 'antioxidants' than their chemically grown counterparts and can be highly beneficial for human health. They have elevated antioxidants levels in about 85% of the cases studied. They have been found to be protective against several forms of 'cancers' and against 'cardiovascular diseases' (Sinha, 2012).

Conclusion

Disposal of the municipal solid waste is a serious problem worldwide. Land application of urban/municipal solid waste can be a good waste management technology as it is rich in organic matter and contains a significant amount of recyclable plant nutrients, but the presence of heavy metals and different toxic substances restricts its land use without processing. Composting of these wastes is a feasible option but compost resulting from the process is low in nutritive value and it is a time consuming process. Vermicomposting of solid organic waste from industrial as well as municipal origin can be a suitable alternative technology for managing this waste. As the end product is pathogen free, odourless and rich in plant nutrients as compared to conventional compost. Agricultural utilization of vermicompost will help in recycling the plant nutrients to soil and also avoid soil degradation. Vermicompost produced by the activity of earthworms is rich in macro and micronutrients, vitamins, growth hormones, enzymes such as proteases, amylases, lipase, cellulose chitinase and immobilized microflora. Vermicompost is optimal organic manure for better growth and yield of many plants. It can increase the production of crops and prevent them from harmful pests without polluting the environment. Application of vermicompost increased growth, improved plants nutrient content, and improved the quality of the fruits and seeds. The vermicomposting of these wastes will be very helpful in tackling the waste disposal problem as well it will be also useful in recycling the plant nutrients present and will convert this waste into useful resource.

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Urban and Peri-Urban Agriculture Practices in Different Countries: A Systematic Literature Review

Kaveya Pugazhendhi¹, Aisha Hameed² and Paul Mansingh J³

ABSTRACT

Urban and peri-urban agriculture (UPA) is the activities carried out on land and in other locations within the cities and their surroundings that produce food and other products through agricultural production and associated processes. A systematic literature review on the urban and peri-urban agriculture practices followed in different countries using the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) method is presented in this paper. Using several search strings and advanced searches, 1014 articles were identified from the Scopus database. Later using inclusion, exclusion, and quality assessment criteria, 32 articles relevant to the subject were included in the study. This systematic review identified the UPA practices in nearly 20 countries like The Netherlands, Kenya, Italy, Nepal, India, Brazil, Ethiopia, Zimbabwe, Argentina, Nigeria, and a few more worldwide. The practices followed in the countries and the critical reasons behind the practices are analyzed in the study. However, in most peri-urban areas, agriculture is followed only for family consumption or for selling the produce in the local markets or communities. Vegetable gardening and mixed farming are the prevalent agricultural practices in urban and peri-urban areas. Co-operative model worker's gardens and collective plots of the shared garden are practiced in France that encourage the united farm work of villagers. UPA is reported to reduce the food miles and supply chain thereby reducing the carbon footprint. Farms cultivating many short-duration crops in a single field for multiple seasons increase soil fertility. Farming kits like 'Do-it-yourself' horticultural kits in India and 'Mushroom growing kits' in Switzerland and other such government kits were used to promote UPA. A greater number of studies were found in the eastern countries when compared with other countries around the world. Further research is required to identify the practices followed in other countries.

Keywords: Urban Agriculture, Peri -Urban Agriculture, Good Agriculture Practices

Introduction:

Urban and Peri-urban agriculture is a need to ensure the food safety and security of the growing urban population in the globe. Urban and Peri-Urban Agri-

1,2&3. Research Scholars, VIT School of Agricultural Innovations and Advanced Learning, Vellore Institute of Technology, Vellore-632 014, Tamil Nadu, India.

Corresponding Author Email: paul.mansingh@vit.ac.in

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culture (UPA) is followed by different practices in different countries as per the need or demands of the people and the suitable environmental conditions prevalent in the country. However, most of the practices include the cultivation of vegetable and fruit crops (Lovell, 2010). UPA is practiced for satisfying the family needs or selling the produce in the local market. Roof top farming and vertical farming practices not only meet the food needs of the people but also reduce the impact of heat on summer days (De Zeeuw et al., 2011).

A systematic literature review is a formal and standard research method for finding, evaluating, and analyzing all studies that attempt to address related topics. A systematic review is a formal research study that follows a well-defined structure to find, review and analyze studies that attempt to answer associated questions. This SLR deals with the different agricultural practices followed by the urban and peri-urban places of different countries.

Methodology

The search was performed in the Scopus database. Various combinations of algorithms were considered, and the outcome of the research was used for the paper. Algorithms included the combination of keywords from each of the following search strings: a) “peri-urban agriculture” b) “urban and peri-urban agriculture” c) “urban and peri-urban agriculture practices” and d) “urban and peri-urban farming practices”.

Initially, the screening was done based on the inclusion and exclusion criteria (Table 1). Later stages of article screening were done based on the title and abstract reading, where the studies related to a) Urban or peri-urban agriculture practices in a country and b) Different agricultural practices in an urban or peri-urban land area were included.

Table 1. Inclusion and Exclusion criteria

Criteria	Inclusion	Exclusion
Initial identification		
Literature type	Research articles	Review papers, Book chapters, series
Source type	Journal	Trade journal
Publication stage	Final	Press
Access type	Open access	Restricted access
Subject area	Agricultural sciences, Environmental and biological sciences	

Language	English	Non-English
Timeline	2013-2023	<2013
Screening		
Title and Abstract	Existence of predefined search strings in the title, abstract, keywords or introduction of the paper. Considered the agricultural practices followed in the urban and peri-urban area.	
Full text	Explained the urban and peri-urban agriculture practices in the State/ country.	

The number of studies from each database using the above-mentioned search strings was presented in table 2. The database search resulted in a total of 1014 articles. From the automation filters provided by the databases, 422 articles were marked as ineligible using the inclusion and exclusion criteria determined for initial identification (e.g. non-English, restricted access, review papers, etc.) and deleted from the records. From the remaining 1229 articles, using the Rayyan software, 337 articles were excluded after duplicate removal.

Further after screening the title and abstract 103 studies were eliminated for not having peri-urban agriculture, non-farmer population, and non-existence of predefined keywords in the title, abstract or keywords as a part of the paper. A total of 32 studies were chosen for quantitative analysis based on suitability, relevancy, and clarity of addressing socio-economic variables.

Table 2. Keywords used and total number of publications from databases

Database	Search strings and search terms		No. of articles
Scopus	Main search-ing terms	"urban" AND "agriculture"	1014
		"peri-urban" AND "farm"	31
		"peri-urban" AND "agriculture"	30
		"urban" AND & AND "peri-urban" AND "agriculture" AND "practices"	128
		"perl-urban" AND "agriculture"	47
		"peri-urban" AND "farm"	31
		"urban" AND "agriculture"	117
		"urban" AND "agriculture" AND "practices"	208
		"peri-urban" AND "agriculture"	4

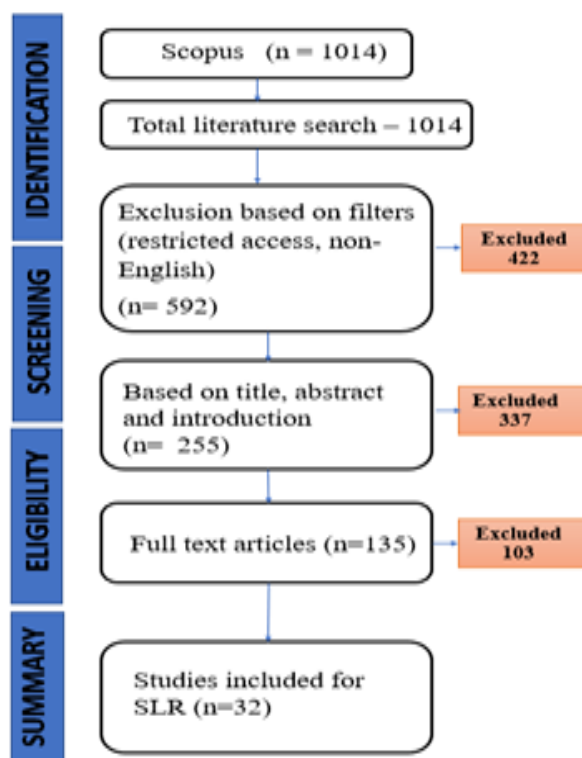


Figure 1: PRISMA flowchart depicting the number of studies inclusion and exclusion for identifying the Urban & Peri-urban Agriculture practice in different countries.

Results and Discussion

The focus of this study was to find the different agriculture practices followed in urban and peri-urban places around the world. In the peri-urban zone of Oosterwolde, Almere, The Netherlands, three types of agricultural practice are followed. Garden farming is practiced on smaller plots of land for kitchen gardening or poultry, while multifunctional agriculture is used for producing market gardens or livestock on larger plots of land. Conventional farming is carried out on even larger plots of land for national or global supply. The first two types are for local food needs, while the latter is for wider supply (Jansma et al., 2022).

In the urban and peri-urban regions of Nairobi, Kenya, people practice composting, open field farming, vegetable nurseries, various irrigation methods, farmyard manure, chicken rearing, multi-storey gardens, kitchen gardens, greenhouses, and cattle rearing mainly. In Turin, Italy, the protected areas of Stupinigi and La Mandria national parks are made greener by the woods and

the oak-hornbeam groves for recreational purposes (Gottero et al., 2021). In the areas of Kirtipu, Madhyapur thimi, Tarkeshwor, and Harsiddhi of Kathmandu Valley, Nepal, people practice vegetable farming, tomato, carrot, and green leafy vegetables. They conduct monthly meetings and use manure-treated vegetables that give higher yields and prices (Rai et al., 2019).

In La Pintana and Lyon of France and Chile, there are workers' gardens and shared gardens, respectively. Lyon, France has over a hundred shared gardens for local and sustainable organic production. These gardens are based on a cooperative model of government policy and collective gardening and harvest. The involvement of local stakeholders is said to be the key to the success of this practice. (Silva et al., 2022). In Italy, UPA on rooftops and the ground is expected to meet the city's vegetable demand (Lucertini et al., 2021). In the Kensington peri-urban plots of Zimbabwe, people have shifted from cultivating maize to mixed farming with horticultural crops and livestock management due to climate change affecting cereal yields (Dube et al., 2021). Zero Acreage Farms numbering 73, in various cities across North America, have Asia, Australia, and Europe, had the potential to promote sustainable urban agriculture by using innovative practices, and farming technologies, and creating new patterns of food supply and urban spaces (Thomaier et al., 2015).

In Córdoba, Argentina, a total variety of 30 vegetable species were found across sampled farms, with 15 most common crops being grown. The practice of diversified farming aims to promote ecosystem functioning and related services such as soil fertility and productivity conservation, as well as crop diversity (Marinelli et al., 2023). In most parts of Nigeria, they practiced mixed cropping, which involved planting more than one crop on a single piece of land. Fluted pumpkin (*Telfairia occidentalis*) is primarily cultivated for its leaves and fruits in Nigeria (Oluwole et al., 2022). The text mentions that only images captured during the dry season with low to no cloud cover were chosen for analysis in Bolgatanga, Ghana. However, using dry season images may result in the misclassification of bare lands and farmlands as their spectral reflectance can appear similar (Kuusaana et al., 2022).

Agricultural activities continue to be practiced in the peri-urban areas of Sogamoso, where the soil is highly fertile, including in vacant spaces between residential and backyards and patios. The crops grown include various vegetables such as chard, chili pepper, celery, and fruits like apples, pears, and figs (Feola et al., 2020). Sixteen varieties of edible plants were grown using cultural techniques for pest control, which resulted in vegetables that were free from pesticides. In addition, converting household green waste into compost to improve soil nutrients and using rainwater and greywater for irrigation

purposes are practiced (Gajbe et al., 2021). In Ethiopia, there is a need to improve milk production, and urban and peri-urban farms are crucial in achieving this goal. Peri-urban farms have more oxen and bulls than urban farms because they practice mixed-crop livestock farming. Common forages used to improve livestock feed quality include alfalfa, elephant grass, Rhodes grass, and sesbania (Balcha et al., 2022). Agriculture takes place through community gardens here. In Cuba, government policies encourage agricultural activities within the cities, including intensive vegetable gardens, gardens in companies and factories, and suburban farms, among other initiatives (Gomes et al., 2019).

In Andalucía, Spain, Collaborative SFSCs provide several benefits, including a variety of products for consumers, sharing of resources among producers, preservation of local food chain infrastructure, increased bargaining power for small producers, reduced competition between small producers, and mutual support to combat isolation and stress (Ochoa et al., 2020). Urban farming systems come in a range of technological levels, from high-tech options to low-tech ones, and are marketed to both professional farmers and consumers in other industries (Van-Tuijl et al., 2018). In Sunqiao vegetables, fruits, and herbs are grown vertically on skyscrapers. In Shanghai, more than half (56%) of the local population prefer leaf vegetables, which grows in hydroponic and aquaponic systems (Zareba et al., 2021).

Table 3. Urban and Peri-urban Agricultural Practices followed

Country	Urban and Peri-urban Agricultural Practices followed
Oosterwolde, Europe	Garden, multi-functional and conventional
Nairobi, Africa	Multi storey gardening, open field farming and vegetable nurseries
Kathmandu valley, Nepal	Vegetable farming
France and Chile	Permaculture, Shared Gardens
São Luís, Brazil	Intensive vegetable gardens, company and factory gardens, and suburban farms.
Venice, Italy	Roof top
Kensington peri-urban plots, Zimbabwe	Mixed farming
New York city	Zero Acreage Farming
Córdoba, Argentina	Diversified farming

Owo, Okitipupa and Akure, Ondo state, Nigeria	Mixed farming
Bolgatanga, Ghana	Irrigation-based vegetable production
Sogamoso, Colombia	Back gardens and patios
Funchal, Madeira island	Integrated kitchen gardens
Nagpur city, Maharashtra, India	Urban rooftop farming
Taipei, Taiwan	Zero acreage Farming

Summary and Conclusion

This systematic review identified the UPA practices in nearly 20 countries. The practices followed in the countries and the critical reasons behind the practices are analyzed in the study. In most peri-urban areas, agriculture is followed only for family consumption or for selling the produce in the local markets or communities. Vegetable gardening and mixed farming are prevalent agricultural practices. Co-operative model workers' gardens and collective plots of shared gardens are practiced in France that encourage the united farm work of villagers. UPA is reported to reduce the food miles and supply chain thereby reducing the carbon footprint. Farms cultivating many short-duration crops in a single field for multiple seasons increase soil fertility. Farming kits like 'Do-it-yourself' horticultural kits in India and 'Mushroom growing kits' in Switzerland and other such government kits were used to promote UPA. A greater number of studies were found in the eastern countries when compared with other countries around the world. Further research is required to identify the practices followed in other countries of the globe.

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