POTENTIAL OF SIMPLIFIED HYDROPONICS TECHNOLOGY AS A RESOURCE EFFICIENT URBAN HOUSEHOLD FOOD PRODUCTION SYSTEM

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Abstract

Low cost appropriate technologies for efficient food production are very much in need for increasing population to grow their own food. Simplified hydroponics is an aggregate hydroponics system which can be used with limited resources such as space, water, energy, labor, time, cost etc. This technology is based on minimal inputs, requiring no green houses, commercial energy sources or expensive equipment. Simplified hydroponics systems are built with recycled or discarded wooden or plastic containers (boxes) filled with inert growing media, having a hole (about 1.5 cm above the bottom) on the container wall which helps to retain water and nutrients. This serves as a water and nutrient store for the plants, minimizing the wastage and also preventing environment pollution as there is no run off. Therefore, hand watering once a day with hydroponics nutrient is sufficient. The low input of labor has enabled this technology to be used by even physically and mentally challenged. This technology has now been adopted in twelve Latin American and African countries and International experience indicate that using simplified hydroponics technology, a 40 m^2 space can provide a family of four with 500 calories each day, or over a pound of fresh vegetables for each. Therefore, it would be very much useful to test the potential of simplified hydroponics for urban food production in Sri Lanka as an appropriate, affordable, and accessible technology option. Three pilot projects have been conducted in Sri Lanka using a new nutrient formula developed by us and patented. The first project was to identify the suitability of simplified hydroponics system for the mentally ill and was conducted at Ridiyagama Mental Health Rehabilitation Centre. Twenty vegetable beds have been successfully managed by the mentally ill for a period of six months. The second project was conducted to test the adaptability of this technology to communities in Hambantota District involving ten households having limited space, for a period of six months, and was successfully completed. The third one was to quantify the space efficiency and to identify the suitability of the system to grow local crops utilizing a balcony space at Nugegoda. The results show that using a space of 3.6 m^2, in 21 rigiform boxes (0.17 m^2 each) having 2 plants /growing bed produced approximately 12.5Kg of total green harvest in a 4-5 month crop cycle. Crop varieties cultivated were tomatoes, brinjoles, bitter guard, long beans, cabbage, beans, okra, and Chinese kale. To produce that harvest the amount of hydroponics nutrients used was 18 liters/box for four month crop cycle costing approximately Rs.50 /box for nutrients. Simplified hydroponics can be recommended as a low cost technology suitable for busy office workers, house wives, elderly or disabled to grow vegetables within a limited space available. New designs, local low cost growing media, arrangement systems are yet to be identified to make this system more efficient.

Key words: hydroponics, urban gardening, low cost gardening

1.0 Introduction

1.1 Household food production and urban agriculture – an overview

Household food production is commonly known as home gardening. Home gardening is defined as "a small scale, supplementary food production system by and for household members that mimics the natural, multilayered ecosystem" (Mitchell 2004 citing Hoogerbrugge and others 1993). It has gained a considerable importance in the world today due to food insecurity and malnutrition caused by factors such as global food and economic crisis, effects of climate change and armed conflicts. Urban poor have been the most affected given their heavy reliance on the cash economy, their being net food buyers and consumers, and no agricultural production to fall back on (Baker 2008). Increasing trend in population and urbanization particularly in Asia, further exacerbate this situation (ADB 2012). Urban agriculture which includes urban home gardening has been looked upon as an important strategy to ensure the food security of urbanites in general and the urban poor in particular. Eight hundred million people are engaged in urban agriculture worldwide with the majority in Asian cities. Of these 200 million are considered to be market producers, employing 150 million people full time (UNDP 1996). A comparative study on 15 developing or transition countries on urban food production revealed that 10-70 % of urban households are involved in agricultural activities (Zezza et.al.2010). The study also highlights that urban agriculture appear to be associated with a diversity of diet and available calories. Home gardens have also been proved to be the repository of micronutrient rich food for consumption, for example to combat Vitamin A deficiency among children and an income generation (Helen Keller International 2012). Home gardening has been an important coping strategy in transition economies such as Russia in the wake of economic crises, playing an important role in real income and food consumption of the middle-income strata. Household plots provide almost 40 percent of Russia's agricultural output (Seeth et.al. 1998). The economic contribution of urban agriculture depends on factors such as profitability, opportunity cost, policy support etc. (Zezza et.al.2010). However, it does contribute to the local economies by diversifying the economic base and yield direct income through sales and labor and indirect income through reduction of expenditures on food (Nugent 2008). An important feature of urban agriculture is that it cuts across all income groups although the majority of people involved are the urban poor. Typically most of urban farmers are women who find it easier to combine small scale farming with their household tasks and responsibilities. On the other hand women tend to dominate urban cultivation mainly because they tend to be marginalized in the formal sector of the urban economy (Mitchell et.al, 2004 citing Hoogerbrugge and Fresco 1993).

1.2 Status of home gardening and urban agriculture in Sri Lanka

In general, Sri Lanka home gardens have been reported to produce 60 %of leafy vegetables and 20 % of all vegetables consumed by the household (Mitchell 2004 citing Hoogerbrugge at el, 1993). However, the traditional home gardening in Sri Lanka has not gained much recognition at the policy and practice level until after the tsunami disaster followed by the global food crisis in 2007/2008. In the aftermath of Tsunami, the western province agriculture department has initiated an urban agriculture program based on the concept of Family Business Garden (FBG) in remodeling and modernizing tsunami affected townships (Ranasinghe 2006). While the family nutrition is the main objective of the FBG concept, the other objectives are; technology adoption, crop management, post harvest technology and value addition, landscaping and housekeeping. This has influenced to promote urban agriculture in the Sri Lanka National Agriculture Policy of September 2007 which says ; 17.0 – Home gardening, 17.1 – Promote home gardening and urban agriculture to enhance household nutrition and income and 17.2 – Promote women's participation in home gardening.

1.3 Opportunities and challenges for urban agriculture

Seven critical reasons to engage in urban farming has identified in an analysis of 17 city case studies. They are (in the order of priority) - 1)Production for home consumption 2)Income enhancement 3)Economic crisis 4)High price of market food 5)Income or asset diversification 6)Supplementary employment 7)Conflict 8)Poor weather(Seeth et.al.1998). Constraints for development and mainstreaming of urban agriculture are access to land, water, and preventing pollution from inputs such as fertilizer. The production systems also needs to adapt and resilient to the impacts of climate change. Sustainable urban food production at household level requires improved productivity of the resources used especially labor, with lesser costs of other inputs. The critical need therefore is to develop appropriate, affordable and accessible agricultural technological options that use space, water and other resources efficiently. Present socio-demographic and environmental trends indicate that this is equally important for both urban as well as for rural areas. Food production technologies that can be used by communities having very small plots of land or by even landless is of significant importance. It is of equal importance to develop and popularize technologies that can be used by physically and mentally challenged and aged population to grow their own food at the household level.

Simplified hydroponics

(a) History

Simplified hydroponics is a vegetable production system that utilizes hydroponics principles adapted for areas with limited resources. This technology is based on minimal inputs, requiring no green houses, pumps, commercial energy sources or expensive equipment. Simplified hydroponics gardens are built with recycled or discarded wooden or plastic containers, hand watered once a day with a commercial hydroponics nutrient. Developed in Colombia in the early 1980s and the technology has now been adopted in twelve Latin American and African countries (Bradely et.al. 2000).

(b) Status in Sri Lanka

Simplified hydroponics technology was transferred to Sri Lanka from former International Institute of Simplified Hydroponics in Mexico with the support from USAID Colombo Office. Initial pilot tests were conducted to assess its technical viability under local environmental conditions (unpublished).

(c) The System

In Simplified hydroponics a wooden box or any discarded container can be used as the bed grower. Inner walls of container are lined with black plastic sheet with a hole about 1.5 cm above the bottom (Fig. 1) which helps to retain water and nutrients. This serves as a water and nutrient store for the plants minimizing the wastage and also preventing environment pollution as there is no run off. The bed grower is filled with an inert medium such as rice hull and sand which provides strength to the plants while supplying sufficient air.

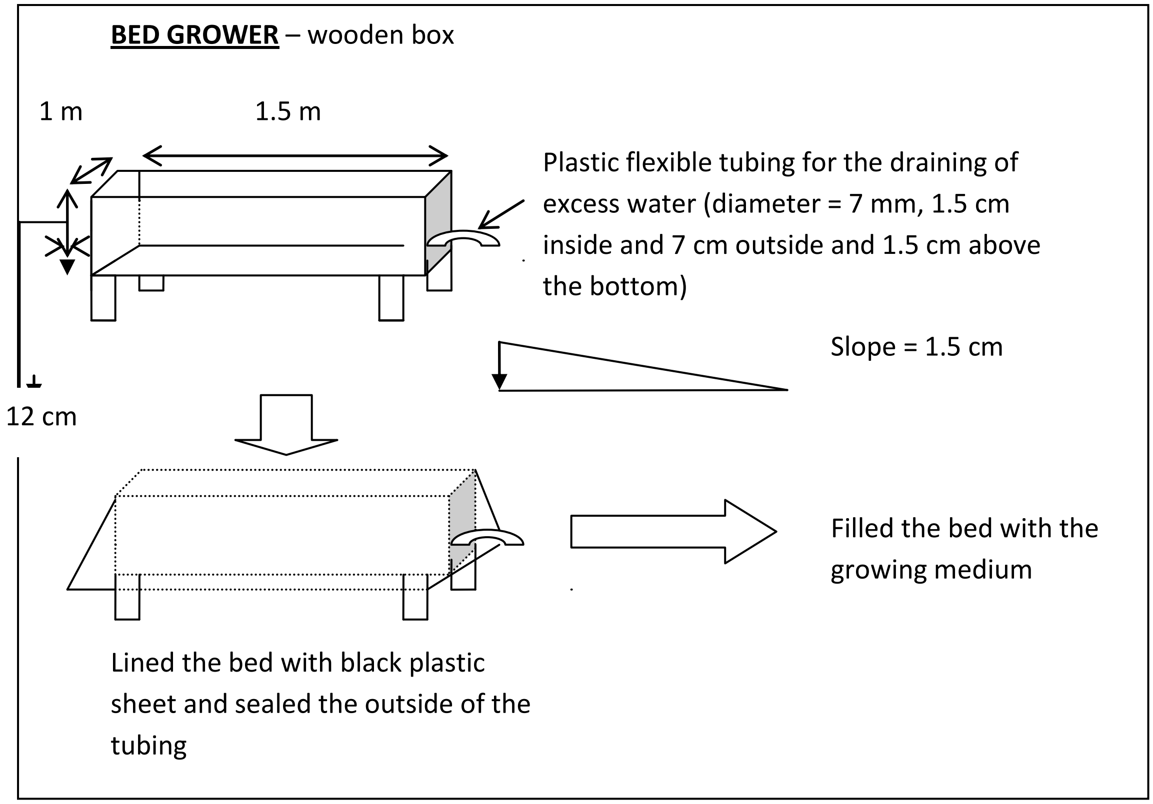

Fig. 1 bed grower (adapted from Bradley et.al, 2000)

2.0 Aims and objectives

This paper presents potential of simplified hydroponics as a technology that can use small plots and places such as balconies, small backyards, walls and other limited space for growing vegetable and fruits for household consumption. Our focus here is on home garden plots that fall under one perch of land.
Main objective of the project was to demonstrate the applicability of simplified hydroponics as an appropriate agricultural technology for different categories of people. Specific objectives are to determine;

1) Suitability of simplified hydroponics as a useful vocation for people recovering from mental illnesses
2) Applicability of simplified hydroponics as an appropriate technology for home gardens with limited land in rural areas or lands with problem soil.
3) Technical viability and the utility of simplified hydroponics for home gardening using a balcony space in an urban setting.

3.0 Materials and Methods

The following characteristics are common for all three projects.

The system: Simplified hydroponic system

The grow boxes we used were commercially available rigiform boxes having dimensions of 42cm (L) X35cm (W) X16cm (H). Grow boxes were prepared as shown above.

Medium used: Rice hull was soaked and washed daily for seven days and mixed with washed (three times) river sand in 3: 2 ratio. Boxes were filled with this medium for 12 cm height.

Table1: Details of crops grown

Vegetable (treatment)	**Planting**	**No. of plants *per* box**
Tomatoes (Lycopersicon esculentum) Variety-Thilina	seedlings	02
Brinjoles(Solanum melongena) Variety-Thinnaveli	seedlings	02
Vigna (Vigna unguiculata) Variety – Havari Me	Direct	02
Bitter Gourd (Momordica charantia) Variety M.C.43	Direct	02
Okra (Abelmoschus esculantus) Variety – M.I.5	Direct	02
Chinese Kale (Brassica oleracea var.alboglabra) Variety - Jumbo	seedlings	02
Cabbage (Brassica oleracea) Variety - Exotic	seedlings	02
Snake gourd (Tricosanthes cucumerina) variety TA-2	Direct	02
Chili (Capsicum chinense) variety MI-2	Seedling	02
Capsicum (Capsicum annum) variety CA-8	Seedling	02

Source of seed material: Land Mark Seeds (Chinese kale) and Department of agriculture (others).

Nursery: Seeds of tomatoes, brinjoles, leafy cabbage and cabbage were soaked in water for a day and planted in seed trays having coir dust and sand in 1:1 ratio; watered for the first two weeks and thereafter fertigated with half strength hydroponics nutrient solution until transplanted.

Direct planting: Seeds were soaked for a day before planting.

Nutrient used: New low cost hydroponics nutrient formulations prepared with commercial grade chemicals were having the following composition (ppm).

GROW formulation - Ca = 234, N = 167, P = 80, Mg = 57, K = 281, S = 251, Cu = 0.10, Fe =3.6, Zn = 0.14, Mn = 1.2, Mo = 0.13, B=0.4

BLOOM & FRUITING formulation - Ca = 234, N = 316, P = 90, Mg = 57, K = 569, S = 251, Cu = 0.10, Fe =3.6, Zn = 0.14, Mn = 1.2, Mo = 0.13, B=0.4

Table 2. Irrigation and nutrient application patterns practiced

Nutrient used	Growth stage	Water /day (ml)	Nutrient/day (ml)
GROW formulation	Until flowering	500	100
	After flowering	1000	200
BLOOM & FRUITING formulation	After flowering	1000	100

On rainy days only the nutrients was applied after draining the rain water collected.

2.1 <u>Project 1 – Determination of the suitability of simplified hydroponics as a useful vocation for people recovering from mental illnesses</u>

2.1.1 Agro-ecological Zone: Dry Zone, Southern Province
Location : Provincial Mental Health Rehabilitation Center, Ridiyagama
Period : July- December, 2003

2.12 Method: Ten mentally ill rehabilitated patients were involved in preparing growing beds, applying nutrients and maintaining twenty simplified hydroponics grow boxes with the help of medical assistants. Tomatoes, cabbage, brinjoles, and okra were planted (Table 1). Only GROW formulation was used for both the grow stages (Table 2). Each patient were given the responsibility to look after one grow box and were asked to draw and record their observations of plants such as new buds, flowers, fruits, insects and pests etc. Observations of the patients' behavior (time spent, interest, communication and interaction with each other) were noted with the help of the assistants.

2.2 <u>Project 2- Determination of the applicability of simplified hydroponics as an appropriate technology for home gardens with limited space in rural areas</u>

2.2.1. Agro-ecological zone : Dry Zone, Southern Province
Location : Hambantota District
Period : November – April, 2012

2.2.2 Method : Eight farmers, one school teacher and one officer from Agrarian Service Center were trained on preparation of simplified hydroponics grow boxes and nutrient solution. Each of them was given 10 grow boxes, nutrients and seeds. All the plants in Table 1 were grown by the farmers according to their preference. Only GROW formulation was used for both the grow stages (Table 2). The amounts of nutrients used and the yield were recorded. An interview based social and technical assessment was conducted to determine the applicability of the technology for home gardens.

2.3 <u>Project 3 – Determination of the technical viability and the utility of simplified hydroponics for home gardening using a balcony space in an urban setting.</u>

2.31 Agro-ecological Zone: Low country wet zone
Location: Nugegoda, Western Province, Sri Lanka
Period: July – December, 2011.

2.32 Method: Twenty one simplified hydroponics grow boxes were set up in a balcony area of 3.36 m^2 (0.000336 hectares). All the plants in Table 1 were grown with 3 replicates (grow boxes). Both GROW and BLOOM & FRUITING formulation was used for the grow stages (Table 2). Yield, time spent, amounts of nutrients and water used were recorded.

2.33 Garden layout:

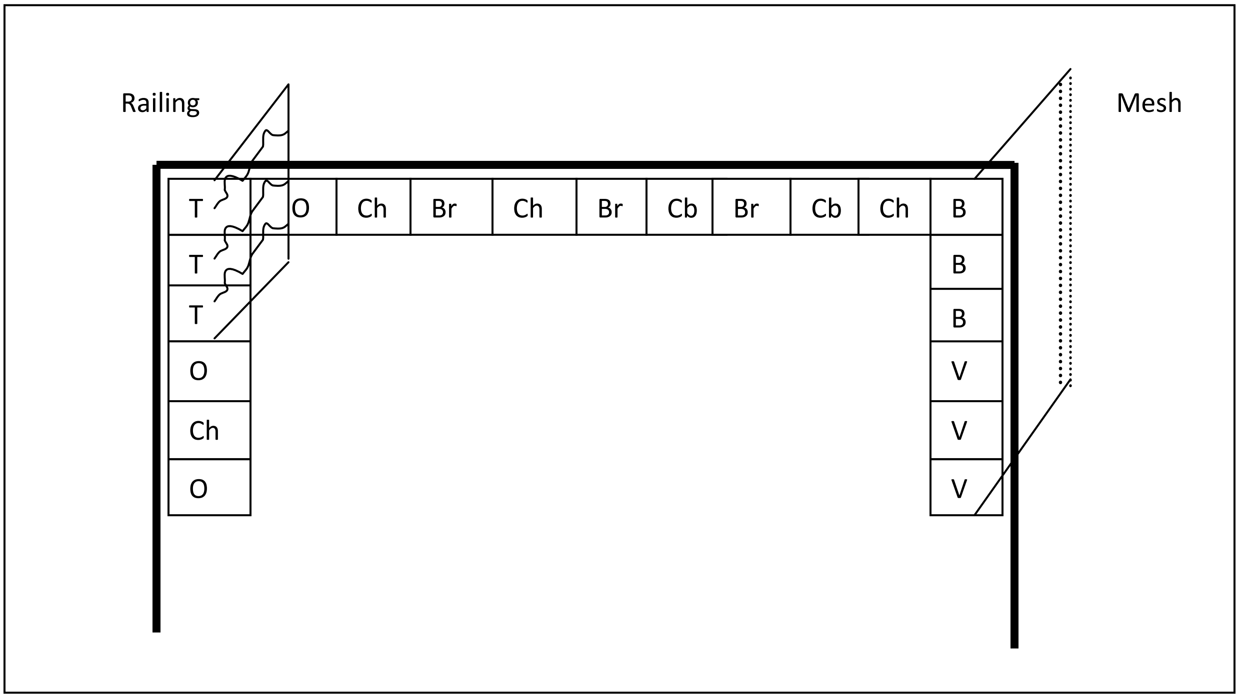

Fig. 2 Layout of bed growers in the balcony
Wall ············· wire mesh bed grower (42 cm x 35 cm x 16 cm= 0.16 m^2)
O = Okra Ch = Chinese Kale Br = Brinjoles Cb = Cabbage B = Bitter guard V = Vigna T = Tomato

3.0 Results

3.1 Project 1 **–** All patients were eager to look after their plants and observed keenly the plant growth. Drew and colored the flowers and pods; discussed the observations with each other. All spent about one hour in the morning and one hour in the evening happily concentrating on the plants without getting exhausted.

3.2 Project 2 **–** Out of the eight farmers selected only six had participated in the full project cycle. Others could not continue due to personal problems. The school chosen had the vacation period and they could not continue. Agrarian Services Center could not implement the project due to some administrative reasons. About 66% (four out of six) participants were house wives with children under five years of age.

Table 3 – Crop Yield and nutrient usage of project 2

Crop	Average Yield/plant (Kg)	Nutrient usage
chilies	01	A 50 L working solution of GROW formulation was sufficient for a grow box (having two plants) for a period of six months.
Capsicum	01	
Tomatoes	2.0	
Okra	0.7	
Brinjoles	1.5	
Gourds	2.0	

Table 4 – Results of socio-technical assessment of the process in the project 2

System Characteristic	Comments from participants
Time spent	All spent less than 30 minutes/day to maintain ten grow boxes. The process could be well integrated into the daily chorus.
Labor efficiency	All agreed that the labor use was minimal for this process.
Operations	All agreed on the ease of operation
Water use	Not determined quantitatively but all were on the opinion that amounts were lesser compared to soil grown crops.
Nutrient solution preparation and use	All have done accurately as instructed.
Land ownership	Only one participant owned land less than 5 perches; others about 25 perches or more.
Reasons for interest in the technology	1. Problem in soil; Interest in new technology 2. Limited land for cultivation and the interest in new technology 3. Ability to engage in home gardening along with other household duties 4. Interest in new technology and to explore the potential for commercial cultivation
Involvement of other members in the family	All the participants had been helped by the husband as well as children irrespective of the age.
Suggestions	1. Inputs supply on commercial basis and extension services need to continue to ensure the sustainability 2. Introduce a drip system for nutrient application and to facilitate in using the technology for commercial agriculture 3. Explore potential for growing ornamental plants and spices 4. Low cost Innovations in the system to use this technology in commercial cultivation of high value crops

3.3 Project 3

Table 5- Number of fruits and yield of project 3

Crop	No. of Beds	Total No. of Plants	Crop Area		Total Yield	
			M^2	Hectares	No. Fruits	Weight Kg.
Tomatoes	03	04	0.50	0.00005	102	3.0
Brinjoles	03	06	0.50	0.00005	35	5.2
Vigna	01	02	0.15	0.000016	82	1.5
Bitter Guard	02	03	0.30	0.000032	18	1.2
Okra	02	03	0.30	0.000032	27	1.0
Chinese Kale	02	04	0.30	0.000032	-	0.6
Cabbage	02	04	0.30	0.000032	04	3.5
Total Green Yield	24	26	2.35	0.000244	-	16.0

Time spent **-** Less than 30 minutes a day to maintain 21 grow boxes.

4.0 Discussion

Main objective of this experiment was to demonstrate the potential and effectiveness of simplified hydroponics as an appropriate crop production technology for different categories of communities in various contexts with particular reference of its use in very small areas of urban houses such as balconies and for rural populace with non- fertile land.

Results of all three pilot projects demonstrated the applicability of the simplified hydroponics technology for various settings and for different categories of people.

The first pilot project demonstrated the potential of this technology as a vocation for people recovering from mental illnesses. Simplicity of operations makes this technology amenable for them with little outside help for such activities as the preparation of the nutrient solution in bulk. Patients' involvement in various activities in maintaining the garden can also be used as a horticultural therapy the effectiveness of which needs to be further explored. This can also be an activity for making people with mental challenges inclusive and prevent them from social exclusion. Amounts of nutrients and water used or plant yields were not recorded for this project since the purpose was to determine the willingness, interest and capacities of people involved to maintain hydroponics gardens with minimum external help. Even though we have not yet conducted a pilot project it is a reasonable assumption that this technology has equal potential to be used by physically challenged people and also the elderly.

Results of the second project showed the applicability of this technology for areas with limited land availability in rural areas. Post project evaluation conducted with the involvement of participating families has revealed the following; 1) Considerable time saving for the maintenance of growing beds. Once the growing beds have been prepared and the transplanting was over it took only 15-20 minutes on average per day for the maintenance of beds. These include the daily supply of nutrients and occasional weeding. It was mentioned that this is well suited for women particularly with small children to balance their daily household chores with home gardening. Those who involved in multiple livelihoods or non-agricultural activities as the main source of livelihood find it easier to cultivate vegetables for consumption at the home garden level using simplified hydroponics since the maintaining of the hydroponics garden could be done at any time of the day at the convenience of the grower. 2) Efficient use of water and nutrients. On average, the consumption of nutrients were about 100ml per day per grow box supplemented with some amount of water during the dry period. Average monthly cost of nutrients to maintain one grow box for a period of one crop cycle which is 4-5 months, is around Rs. 80/=. One participant applied higher doses of nutrients expecting higher yields that resulted in excessive vegetative growth and waste of nutrients. This indicates the particular importance of technical training on nutrient management in popularizing this technology for wider adoption. Even though the exact amount of water used were not quantified, it was mentioned that the amounts were far lesser compared to what is required to irrigate a similar plot of soil grown crops. 3) Space use efficiency. Grow boxes could be placed anywhere if sufficient sunlight is available for the crop. In most cases participating families placed their grow boxes in close proximity to the household for easy maintenance.

Findings of the third project were similar to the findings of the second project in terms of labor, nutrients, water, and space use efficiency. While we do not have data to compare the amount of water required for soil grown crops, the amounts used for simplified hydroponics should be less since the percolation and run off is absent in the system. Therefore, the pollution and wastage is minimal and the growing area can be kept clean and tidy. For arid regions this technology can be easily coupled with the rainwater harvesting to ensure household food security during dry spells. Given the present trend of youth evading agriculture, this technology can be an attractive alternative to more tedious soil based agriculture to supplement any other income generating activities. Youth and children can experiment this as a hobby since this technology requires very low capital to start.

Crop yield is considerably higher (at least 2 times)compare to potential yields that could be obtained under soil grown conditions for similar crop varieties as recommended by the Department of Agriculture (Table 6). This is a distinct advantage of the hydroponics technology in general.

Table 6 - Crop yield comparison of simplified hydroponics with soil grown crops

Crop	Potential Yield in simplified hydroponics calculated (Tons /ha)	Yield in soil (Tons /ha)
Tomatoes	60	20
Brinjoles	104	25
Vigna	93	12
Bitter Guard	37	20
Okra	31	15
Chinese Kale	18	N/A
Cabbage	109	40

In the third project, the total green yields obtained from 21 grow boxes or 3.6 m^2 space is sufficient to cover about 70 per cent vegetable requirement of a person for a period of 5 months at the present rate of per capita vegetable consumption in Sri Lanka which is about 150g day (personal communication).

Accordingly, if simplified hydroponics technology is used, the space required to satisfy the vegetable needs of a family of four will be around $9.4m^2$. Above all, pesticide free fresh produce improves the health of growers and consumers while the green environment creates a peaceful atmosphere. These findings are important in designing urban homes and flats with provision of some space for agricultural production.

5.0 Conclusions and recommendations

Results of all three pilot projects confirmed the main advantages of this technology in relation to its time and labor and resource use efficiency which enables agricultural activities to couple with formal jobs and other household chorus. Once the garden is set up with grow boxes, the main daily routine is the application of nutrients and water which takes only 15-20 minutes a day. This can be done at an appropriate time, either early morning or even late evening without making disruptions to other scheduled activities. Growth of weeds is rare and even then the weeding is very easy. Pest attacks can be minimized since the garden is within the house premises itself. The grow boxes can be recycled and reused. Nutrient and water use efficiency is another important advantage in using this technology.

Further investigations are needed to test this technology in different agro-climatic zones in Sri Lanka to determine its resource use efficiency, yield performance, economic viability and socio-cultural acceptance for different categories of people; urban, rural, men, women, youth, elderly, disabled, poor, middle class etc., Further, the possibility and the economic viability of making grow boxes using UV resistant plastics, low-cost wood, clay and other materials needs to be explored to provide consumers with greater choice and to be attractive aesthetically. Possibility of using other types of low cost material or underutilized products such as saw dust, as the growing media should also be investigated. There is also a demand for semi-automated designs for nutrient application for those interested in commercial agriculture using this technology. Designing urban flats or individual homes with balconies or small spaces to practice Simplified hydroponics can provide appropriate choices and options for urban population to engage in urban agricultural activities. Simplicity of the system and labor and time efficient operations in using simplified hydroponics technology can be a further impetus for required attitudinal and behavioral change for people to engage in agricultural activities. This can also be a stress releasing activity for busy people. In order to popularize this technology and to scale up its sustainable adoption, what is required is a multi-faceted market based approach involving a wide range of private, public and non-profit stakeholders.

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