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Reduce Green House Gas (GHG) emission through the best practices of Organic Waste Management; A case Study at Kasbewa Urban Council, Sri Lanka

L. Manawadu

Department of Geography, University of Colombo, Sri Lanka

Abstract - Prevailing systems of the world have induced human life for convenience and efficiency through productivity; that most of the time the soul existence of mankind has been neglected. Rapid growths of economies lead humans towards overconsumption which resulted in accelerating the production of waste. It is one of the main reasons of the production of Green House Gases (GHG), despite polluting our very one habitat. Therefore this study focuses on reducing Green House Gas emission through the Best practices of Organic Waste Management. The area of study is Kesbewa Urban Council (KUC) which is located 20km away from the commercial capital of Sri Lanka but also a highly urbanized region. Main objective of the study is to monitor and calculate the reduction of net GHG emission due to recycling and reuse of organic waste through the process of production of compost in Kesbewa Urban Council area. This study was focused on two household groups where one group practiced home gardening and composting utilized food and other organic waste for home gardening purposes. The other group was the control group that did not practice home composting and home gardening at all. Data were obtained from under different parameters from the sample of 20 houses, including secondary data for collection and transportation of municipal waste. Laboratory tests were also used in identifying Nitrogen (N), phosphorous (P) and Potassium (K) levels of composite samples. The study identified that the households who have larger land engaged in home gardening in the KUC. The study also provided evidence for the reduction of the amount of waste collected by the KUC, contributing to the reduction of GHG emissions. It has also shown that reusing of organic fraction of wastes for composting and its subsequent use for urban and sub urban agriculture could be used as an indicator for reduction of GHG emissions.

I. BACKGROUND

The rate of urban expansion has direct influence on solid waste generation all over the world. Ten years ago there were 2.9 billion urban residents in the world who generated about 0.64 kg of Municipal Solid Waste (MSW) per person per day (0.68 billion tons per year). Today this has increased up to about 3.5 billion residents, generating 1.47 kg per person per day (1.9 billion tons per year). By 2025 this will likely increase up to 4.3 billion urban residents generating about 1.61 kg/capita/day of municipal solid waste (2.5 billion tons per year) (World Bank, 2011). In Low Income Countries, on average, around 50% of the Municipal Solid Waste is collected and only less than 25% properly dispose. Uncollected MSW is usually the second largest source of air pollution in most cities in Low Income Countries (especially particulate emissions). Uncollected, and collected, MSW, leads to Methane (CH_4) generation through anaerobic decomposition (though this methane may be captured for energy use). GHG emissions from MSW have emerged as a major concern as post-consumer waste is estimated to account for almost 5% (1,460 mtCO2e) of total global greenhouse gas emission. Encouraging waste minimization through MSW programs can therefore have significant up-stream GHG minimization benefits. Reduction of collection efforts will also contribute to reducing transport and related GHG emissions.

In most of Low Income Countries, over 50% (up to 90% or more in some cases) of all municipal waste consist of organic matter. Composting is a sustainable waste management option for processing the organic component of wastes (discards of food, agro-industries, vegetable markets, trimmings from yards, parks and forests etc.). Composting (aerobic fermentation) is importance as a sustainable MSW reduction method due to its ability to reduce Methane and ability to produce a useful soil conditioner as an end product (especially if MSW is linked to urban agriculture). For this concept the quality of waste should be highly considered, such as waste should be properly segregated at the source and shouldn't be mixed with hazardous components etc. Waste separation and possible sieving - done at larger scale, may involve extra energy costs. Therefore, Carbon finance may be an important catalyst for waste management improvements in low-income cities (World Bank, 2011).

Waste composition and product life cycles are vary significantly across the countries. For example, food habits of people and types of industries will determine the quality of the waste streams. Each country will have to develop a methodological framework and benchmark data for developing GHG emission estimates for their solid waste streams. Typically, the major components are household waste, garden (yard) and park waste; and commercial/institutional waste. It has been estimated that over 6400 tons/day of solid waste is generated in Sri Lanka, between 0.25-0.5 kg/day/person (Wijetunga, S. 2001). The most common practices for waste management implemented by many municipalities in Sri Lanka include open burning, land filling and open dumping which are not considered as environmental friendly or sustainable method. Waste that is improperly dumped anywhere provides breeding places for disease vectors such as rats and mosquitoes there by causing human health hazards. It can impede water-flow in drainage channels influencing flooding during periods of rainfall, and create stagnant pools afterward. This cause pollution of ground and surface water, reduce the aesthetic beauty of the neighborhood facilitating illegal encroachments into natural areas simultaneously contributing broadly to change the global climate via increasing methane emissions. Therefore, the environmental problems they often create are immense (Visvanathan, 2006, Zon and Siriwardene, 2000). The volume and character of solid waste increases with the rising standard of living and the expansion of service facilities, however, can be managed through reduction, reuse, recycling and final disposal in an environmentally friendly manner at micro level (in homes, institutions such as schools, offices, etc.) or macro level as in urban or municipal councils (Forbes et al., 2001).

According to figures from the World Bank in Colombo, the water-content of municipal solid waste is around 70%, and the caloric value of the waste some 600–1000 calories per gram (Zon and Siriwardene, 2000) However, the next major component of municipal solid waste in Sri Lanka contains degradable organics (food and garden wastes of animal and plant origin) than non-degradable inorganics such as metal, glass, rubber material, textiles and paper (Visvanathan, 2006 and Perera, 2003). According to Zon and Siriwardene (2000), Waste production of the households measured seems to be in the range of 100-300 g per day, not including waste materials that were recycled or re-used at the Ja-Ela DS Division in the Gampaha District of the Western Province. Further, they state that the average composition of the household waste (by weight), was 15%–30% plastics, 30%–40% paper, 0–30% organic fraction and 10%–30% rest-fraction. The plastic and paper fractions made up most of the volume of household waste, while the organic fraction makes a relatively large contribution to the total weight, due to its high density and water-content. In addition, packaging materials create more than half of the plastic and paper fractions, both by weight and by volume.

As a waste management practice, home composting of fresh organic waste was introduced to the urbanities through the National Strategy for solid waste management project of the Central Environment Authority in 1999. However, majority of the waste generated in urban areas also end in direct dumps on approved sites (Jagath et al, 2002).

Composting not only reduce the quantity of organic wastes added to the environment everyday but also help to minimize financial costs on fertilizers and pollution due to use of agro chemicals (Drescher et al, 1999). Indirectly it helps to reduce the emission of greenhouse gasses due to burning of fossil fuels. Thus provide ecological and economic benefits to citizens.

According to the World Bank (2010), based on *A city-wide approach to carbon finance*: Carbon partnership facility innovation series, re-use of organic solid waste in urban or peri-urban agriculture through composting and anaerobic digestion was highlighted. This is of vital importance as such municipal solid waste management options directly contribute to reduce Methane emissions from landfills while providing a useful soil conditioner to urban agriculture. Therefore at present, attention of scientists is paid on the strong correlation between the utilization of organic waste (composting), agriculture in urban and peri urban areas and subsequent of reduction of GHG emissions to mitigation of anthropogenic climate change.

Decomposed organic waste utilization in agriculture improves soil quality by increasing soil microbial activities, soil air circulation, soil fertility and water holding capacity of soil. It reduces the need for chemical fertilisers, the related use of energy emissions of GHGs (NO_2 and CO_2), reduces nitrate leaching and sequesters carbon in the soil. Energy and GHG emissions could be reduced by recycling food and agricultural waste through compost formation and its usage as an organic fertilizer. The multiple benefits of composting and its subsequent use include reduce production of artificial fertilizers, lower the depletion of minerals such as phosphorus and nitrogen, reduce energy needed for production of fertilizers, reduce transport of waste to landfills and emissions related to transport of waste, reduce Methane emissions from landfills. These benefits have to be offset against the potential for Methane that can be captured, at landfill sites and energy (biogas) that could be produced. Use of compost will also support carbon sequestration and/or increased carbon storage, in plant tissues as well as in soil which will improve porosity and water infiltration capacity of soil. Therefore, Composting of solid organic waste has direct impact of reduce water pollution, air pollution and soil degradation. Furthermore, Composting can be combined with controlled fermentation and production of bio-gas as a renewable energy source.

Most studies on organic and conventional food production as well as climate change mitigation favoured reduction of GHG emission through organic food production and valued the absence of synthetic fertilizer usage and high carbon sequestration through the soil.

Likewise, the use of compost in urban agriculture has the potential to reduce synthetic fertilizer-energy usage in to a greater extent, even if urban agriculture production is depend on fertilizer based method. In many urban agriculture, fertilizer is used, but only in small quantities.

II. OBJECTIVES

The principal objective of this study was to monitor and calculate the reduction of net GHG emission due to recycling and reuse of organic waste through the process of production of compost in Kesbewa Urban Council (KUC) area. For this purpose the study was designed to

i) Identify the importance of composting of the organic fraction of solid waste and its potential use in urban agriculture (home gardening)

ii) To provide evidence, a case study conducted to evaluate reduction of waste transportation from collection in the municipal area to landfill and synthetic fertilizer usage by households due to home composting in urban and peri urban agriculture

iii) To determine the potential reduction of Green House Gas emissions due to home composting of the organic fraction of solid waste and its subsequent use in urban and peri urban agriculture

III. HYPOTHESIS OF THE STUDY

It is assumed that the net GHG emissions from composting are lower than landfilling especially for food discards. Furthermore, CH_4 emissions from composting is significantly low when compare to CH_4 emitting by landfilling. As an example, for yard trimmings landfilling is credited with carbon storage as a results of incomplete decomposition of yard trimmings.

Overall, calculations are done with assumptions based on the settings and therefore, a degree of uncertainty in the analysis is expected especially when proxies are used that may not necessarily be applicable for the local situation.

However in some countries emission factors for composting or combusting these organic fractions of waste materials are considered to be similar. According to RUAF (2013) it is hypothesized that, composting of the organic fraction of urban solid wastes (and subsequent use of such compost in urban or peri-urban agriculture or green areas) might qualify:

1) To reduce the need of artificial fertilizers usage in food production (and thus also lower the depletion of minerals like phosphorus and nitrogen and as well as reduction of the energy needed for production of synthetic fertilizers
2) To reduce transport of municipal waste to landfills and thus reduce GHG emission related to due to transport
3) To reduce landfill volumes and thus minimize Methane emission from landfills (however this methane may be captured for energy use which would off-set emissions)

However, as many cases in Sri Lanka, all household waste in Kesbewa Urban Council area may not be collected but burned or dumped. As mentioned earlier, these practices result in releasing additional GHG emissions to atmosphere. As calculations are very hard to make, in his study assumed that all wastes (in an ideal situation) were collected and sent to a landfill/ waste management center.

IV. STUDY AREA

The study area is Kesbewa Urban Council (KUC) that encompasses 50.39 km^2 in the Colombo district located in the Western province in Sri Lanka. KUC lies on the Colombo-Horana main road about 20km away from Colombo, the commercial capital of Sri Lanka and is part of the Colombo urban fringe. Due to that population has been rapidly increasing in the area, presently accommodate 152,657 inhabitants (*Figure 1*) within KCU area. The area is also characterised by rapid conversion of agricultural land use to urban land use, therefore land cover has been changed over the past few years. The KUC is located in the Low country Wet zone which is classified based on the altitude from the mean sea level and annual rainfall of Sri Lanka (Department of Meteorology, Sri Lanka). The KUC study area has four rainy seasons; the first Inter-monsoon period from March to April, the Southwest monsoon period from May to September, the Second inter-monsoon period from October and November and the Northeast monsoon period from December to February.

During the Southwest monsoon period, the area receives more than 500 mm rainfall, while during the second inter-monsoon and the northeast monsoon periods the area receives more than 200mm average rainfall in some months.

The average air temperature of KUC area for last 5 years (2008 to 2013) is 28.05 ^{0}C, ranging from 31.33^{0}C (maximum) temperature to 24.50^{0}C (minimum) with some significant deviations. During the Southwest monsoon period (May to September) average temperature is relatively low when compared with the 1st inter monsoon period and the Northeast monsoon period. The hottest season of the KUC is January to March. During 2008 to 2013, the KUC area has shown an increasing trend in air temperature, which might be a result of rapid urbanisation in the Colombo and KUC areas.

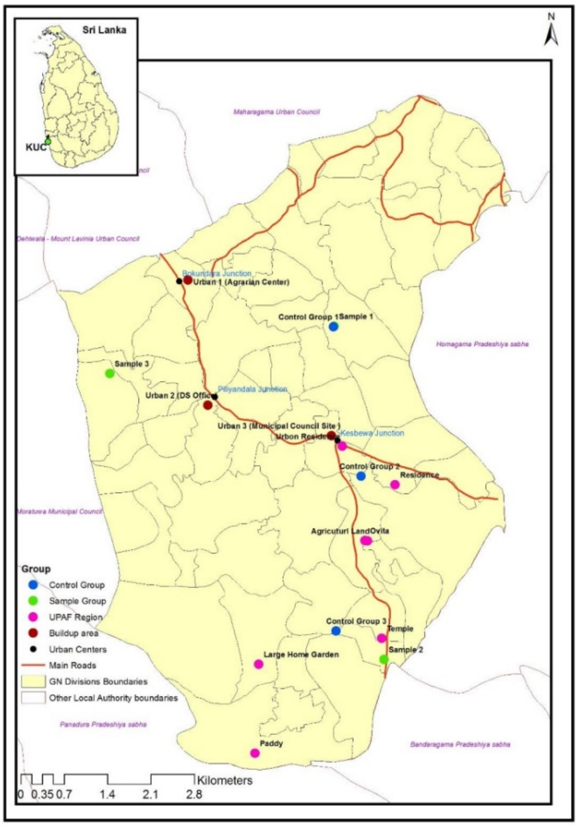

Figure 1: Kesbewa Urban Council area in Sri Lanka

V. METHODOLOGY

This study was focused on two household groups of the same sample size (n=20). One group practiced home gardening and composting (HHS – Project monitoring group) utilized food and other organic (mainly agricultural) waste for home gardening purposes. The other group (HHC – Control group) did not practice home composting and home gardening at all. The HHS also had a home garden in which they grew few herbaceous and woody crops. In contrast the HHC had no trees (or a green cover) in their residential premises. However these two groups did not have similar socio-economic characteristics. Records/Data collected at the beginning of the study included family income, extent of land, food habits. Records indicated that there were differences in above mentioned data categories in both groups and also this two groups did not have similar socio-economic characteristics. According to records collected, the HHS mostly belongs to the low income group when compared to the HHC. Hence, the two household groups were not compared other than home gardening and home composting and expresses as two case studies.

In this study different data collection tools were used to obtain information. Most of the household information was collected using interviews conducted by the enumerators.

The following data were obtained from project monitoring group (HHS):

a). The amount of compost (kg) used and produced (from household and agricultural wastes).

b). Compost bought (compost produced elsewhere)

c). In case of the compost was bought or obtained elsewhere: What have been the source(s) of the bought compost? At what distance from the plot, with what type of transport (type, tonnage) it was transported to the household?

d). Amount of synthetic fertilizers used on the plot(s) of the UPAF project? Type of synthetic fertilizer used, NPK ratios of the applied synthetic fertilizers

e) Same questions used for synthetic fertilizer and compost such as source / distance / transport.

From both project monitoring (HHS) group and the other group (HHC) the following information was collected:

f) The frequency of their household wastes (including organic and non-organic fractions) collected by the Municipality and the amount of household wastes collected each time (kilograms).

Data related to collection and transportation of municipal waste was obtained from the KUC when necessary. Interviews with fertilizer manufacturers, traders and salesmen revealed details on fertilizer manufacture and sales.

At the commencement, households in HHS and HHC were provided with commercially available domestic weighing scales and polythene bags (18"x 24") of seven different colors for 7 days to collect their daily food waste. They were requested to weigh the food and agricultural waste before any usage/discard and record on the data sheet provided. Daily visits of the enumerator and short discussions with the household (mainly the housewife) in each selected families, assisted to collect data for this study. Information on the quality and quantity (weight) of daily wastage of food and agricultural residues, weight of waste disposed through the council dump truck, purchase of any fertilizer by households, weight of compost produced at home and used by the HHS were obtained through the discussions.

A composite sample of the compost used by the HHS were analyzed for Nitrogen (N), phosphorous (P) and Potassium (K) levels using standard methods (Appendix 01) at the laboratory of the Department of Earth Sciences, University of Moratuwa, Sri Lanka

The benefits of recycling food and agricultural waste through home composting and reduction of energy and GHG emissions were compared between the compost producers (HHS) and the non-compost producers (HHC).

Using the data/information listed below, calculated emission reductions due to re- use of organic waste at Kesbewa home gardens

Information of household involvement in home composting and home gardening:

a) The volume of organic waste needed to produce the amount of compost bought and used in the project area (per unit of land).
b) The amount of household organic waste used by the producer for their own compost making and use in UPAF
c) Amounts of nutrients added to cultivated areas of the home gardens of HHS.

This included the amount of NPK nutrients included in the home produced and bought compost that was applied per unit of land in the project plot(s) during the monitoring period

The amount of the synthetic fertilizers were replaced by the nutrients in the compost in the UPAF plots per unit of land per year (taking the NPK contents of the locally most commonly used synthetic fertilizer types as reference)

The energy costs (CO_2 equivalent) related to production and transport of the synthetic fertilizers that were replaced by the compost used in UPAF per unit of land

a) The fuel use (CO_2 equivalent) would occur if this amount of wastes collected and sent to the landfills
b) The GHG emissions from the landfills due to disposal of this amount of organic wastes
c) Energy use (CO_2 equivalent) in the production and transport of bought compost to the producer's plot per ton
d) The difference in emissions between synthetic fertilizer application in the field and compost (for the amount of NPK in the compost applied per unit of land)
e) Net reduction in GHG emissions (per unit of land of this UPAF type)
f) The total area of available/suitable land for this UPAF type in the city region

The potential net reduction in GHG emissions for a city-wide scenario.

VI. RESULTS

i) Identify the importance of composting of organic fraction of solid waste and its potential use in urban agriculture (home gardening)

A) The households involved in home composting and home gardening (HHS)

The average land ownership for HHS was approximately 2000m^2 and average home gardening area/cultivated area was about 500m^2(approximately 25% of their total land).

During the monitoring period, total of 6055 kg of fresh organic waste and 725 kg of non-organic waste (all together 6780kg) were generated by HHS group (n=20). The non-organic waste mainly consisted of polythene and polystyrene bags and packing material, plastic material such as yoghurt cups, newspapers and cardboard. It excluded glass and metals. The main component of organic waste was the fresh vegetable parts scraped during preparation for cooking, trimmings of the trees, bushes and plants from the home garden (agri waste) and cooked food leftovers. Therefore, the average collection of fresh organic and non-organic waste per household from the sample was 302.75 kg (6055/20) and 36.25kg (725/20) per week per household respectively. The HHS had an average of 11.64 kg fresh organic wastes generated and collected per household per week. The KUC collected household waste once a week throughout the project period and these waste were disposed at Karadiyana, in KUC. Karadiyana is the nearest waste disposal site for the study area. Average distance to the disposal site from the center of study area is about 3km and frequency of waste collection by KUC from houses per week was one (Table 1).

Table 1: waste generated by hhs and disposal by the kuc (july- december 2013)

Type of waste	Amount (kg)
Total Food waste	4841
Total Agri-waste	1214
Total Organic waste	6055 (302.75**)
Total non-organic waste	725 (36.25**)
Total	6780

Source: Survey Data (2013)
** Average waste production per HH

Despite the rains of the South-West monsoon period which provide practical difficulties in home composting due to continuous wet conditions, the sample or HHS was able to produce 1665 kg of homemade fresh compost using the barrels provided to them by the KUC (approximately 3.20 kg average production per household per week over the monitoring period). However, they also depended on a considerable amount of compost purchased from the local market for their home yards. During the project period, total of 1594kg compost were bought by 20 HHS, or, average compost purchasing was approximately 3.06 kg per household per week. Also they purchased total of 60Kg of synthetic fertilizers for their home gardening (Table 2). All these were bought from the agrochemical distributors located at the center of the city which was approximately 3km distance from the HHS. The list of local fertilizer distributors are given in Table 3. It was revealed that the compost and synthetic fertilizer they have purchased was not stored but, utilized during the monitoring period. The details of their fertilizer purchase (place, amounts etc.) and Nitrogen, Phosphorous and Potassium contents of the compost they produced and bought outside are given in Table 4.

There are seven (07) fertilizer venders in the study area (Bokundara Agrarian Service center-Bokundara, Ruksewana Plant Nursery-Moratuwa Rd, Piliyandala, Ranka Trading-Kesbewa Road, Piliyandala, Ransaru Plant Nursery- Piliyandala, Agri Shop-Maharagamara Road,Piliyandala, Mahitha Agro Center-Piliyandala, Malshari Plant Nursary-Mawittara,Piliyandala).

(B) The households not involved in home composting or home gardening (HHC)

The average extent of the land of HHC was approximately $330m^2$. The HHC had only collected an average of 1.39kg of non-organic wastes per household per week. As the HHC was not involved in home composting or gardening, they did not have the practice of sorting of the generated waste into organic and inorganic components. But they were requested to collect and weigh the waste given to the KUC municipal waste collection during the project period. This data were considered and analyzed as a second case study of the project. Therefore, total weight of 955.1kg of unseparated waste (containing both organic and non-organic fractions) were collected from the 20 households of HHC during the monitoring period. It was also identified through individual discussion that part of the HHC household waste was not given and not collected by the municipality as some HHC were burned or dumped their waste within their property on daily basis every other day basis. The information on type of waste that they have burnt and frequency of burning practice at home were not regular, hence it was unable to enumeration. It was clear that this group of households do not pay much attention on the type of waste they burn and more waste burning take places just after the waste collection by KUC. As the KUC collects waste from households once a week, and HHC did not pay attention on practice of composting, the generated wastes were not kept in their houses or in their gardens for a longer duration to be collected by the KUC in the next week. Therefore, HCC households preferred to burn any organic or non-organic waste they generated. This could be the reason for less amount for waste generation indicated in the HHC records. This continues waste burning practices in their properties, would also result in additional GHG emissions to the surrounding atmosphere. However, calculation on GHG emission by HCC waste burning is very hard to make due to various unmeasurable reasons.

As mentioned earlier, during this monitoring period, a total of 1680kg of waste were collected from HHC and HHS transported to the Karadiyna waste disposal site by the Urban Council dump truck/lorry. Out of this amount, 725 were non organic wastes collected from the 20 HHS (Table 5).

Table 2: information on compost and synthetic fertilizers used by the HHS

Type of Fertilizer Used	Amount used(Kg)	Distance Travel to carry fertilizer(Km)		Method of Transport used to carry fertilizer	
		HHS to Distributor	Distributor to factory	HHS	Distributor
Homemade Compost (Used barrel method)	1665 (83.25)	N/A	N/A	N/A	N/A
Compost bought outside (Compost from Open Dump)	1594 (79.7*)		N/A	Diesel Van 200Kg	N/A
Synthetic Fertilizer (in a mixed form)	60 (3*)		25	Diesel Van 200Kg	Diesel Lorry 2MT

(Source: field survey, 2013)
** Average per HH in parentheses (kg)*

Table 3: Content of Nitrogen, Phosphorous and Potassium in Compost

Sample Type	Nitrogen (%)	Phosphorus (%)	Potassium (%)
Homemade compost	1.65	0.62	1.9
Compost purchased	1.725	0.55	1.75

*(*Percentage expressed per fresh weight basis).
Source: Laboratory analysis at University of Moratuwa, 2013

Table 4: Details of fertilizers used by the households in Kesbewa UC area

Fertilizer Type	Producer	Distributer	Ingredients/Method of production
Compost	"Green Force Agriculture" ,Kesbewa	Ruksewana Plant Nursery-Moratuwa, Piliyandala	Cattle manure, Green manure, Brown manure, peel, Core dust, Dolomite, ERP, Gliseria OPEN PIT in factory 60 days
		Ransaru Plant Nursery-Piliyandala	
	"Saru Carbanika Pohora" TMN Dharmasiri, Dunkannawa, Nattandiya	Bokundara-Agrarian Service center-Bokundara	Organic soil conditioners, cattle manure, Greenmanure, dolomite, chickenlitter, paddy husk ash (Non chemical) OPEN PIT in factory 60 days
Chemical	"CIC", Wijewardane Mawatha, Colombo 10	Ruksewana Plant Nursery-Moratuwa,Piliyandala	N 12%, P 6% , K 12%
	"Lak Pohora", Lanka pohora company, Hunupitiya, Wattala (Mahindachitanapohora Subsidy)	Bokundara Agrarian Service center-Bokundara	

Source: Field survey, 2013

Table 5: Generation of wastes by HHC and its disposal by the KUC (July- December 2013)

Type of waste generated by HHC during the project period	Unseparated waste
Total weighted waste during the project period (Kg)	955.1
Frequency of waste collection by KUC from houses	Once a week
Location of the waste disposal site	Karadiyana
Average Distance to waste disposal site (Km)	3
Amount of Waste collect by KUC Diesel truck(Mt)	5

ii) Calculations and Indicators for monitoring emission reductions due to re-use of Organic wastes at Kesbewa home gardens:

(A) <u>Amounts of nutrients added to cultivated areas of the home gardens of HHS</u>

The nutrients (N, P, and K) were supplied to the cultivated area of HHS through homemade and purchased compost (Table 2 and Table 3) and by synthetic fertilizers (Note: The average cultivated land size in HHS is 500m^2). The households revealed that all homemade and purchased compost and artificial fertilizer bought by HHS were added to their cultivated areas/home gardens during the project monitoring period. Therefore

- Amount of home compost added to unit area of cultivated land in HHS = 83.25/ 500 = 0. 1665 kg per m^2.
- Amount of purchased compost added to unit area of cultivated land in HHS = 79.7/ 500 = 0. 1596 kg per m^2.

- Amount of artificial fertilizer added to unit area of cultivated land in HHS = 03/ 500 = 0. 006 kg per m^2.

The average amount of nutrients added per unit area of land by the HHS during the monitoring period is calculated below.

As given in the Table 3, N, P, and K amounts in homemade and purchased composed did not differ largely, but the exact percentages were considered for following calculations.

Therefore, amount of nutrient added to unit area of the cultivated areas of home gardens of HHS is = (amount of compost/ fertilizer added per m^{-2} * % nutrients of NPK in compost/ fertilizer)

Hence, Nutrients added from compost:

- From home compost

N= 0.1665 *0.0165 = 0.0027kg per m^{-2}
P = 0.1665 *0.0062 = 0.00103kg per m^{-2}
K =0.1665 *0.0190 = 0.0032kg per m^{-2}

- From purchased compost:

N = 0.1596 *0.01725 = 0.0027 kg per m^{-2}
P = 0.1596 *0.0055 = 0.00087 kg per m^{-2}
K = 0.1596 *0.0175 = 0.0028 kg per m^{-2}

Therefore total N, P, K coming from compost per cultivated unit land area of HHS is (by adding above) N = 0. 00054, P= 0. 00189, K= 0.0059 kg per m^2.

In addition, N, P, K were also added to soil via synthetic fertilizers. Therefore, N, P, K applied per unit area of land from synthetic fertilizers, is also given below. The artificial fertilizer contained N 12%, P 6%, K 12% (as per details of chemical fertilizers, i.e. Table 5. Nutrients added to soil) from synthetic fertilizers

N = 0.006 * 0.12 = 0 .000708kg per m^{-2}
P =0.006 * 0.06 = 0.00036kg per m^{-2}
K =0.006 * 0.12 = 0.000708 kg per m^{-2}

Because of nutrients in synthetic fertilizers occur as N, P_2O_5 and K_2O respectively, conversion factors were applied for K and P to identify them in elemental forms. This is because; during the laboratory chemical analysis of compost NPK values were determined and expressed as a percentage of their elemental weights.

Conversion factors used here for fertilizer are K =0.83 * K_2O and P = 0.436*P_2O_5 (www. wikipedia.org/wiki/NPK_rating, accessed 12. 1.2013). Therefore N P and K added to unit land (cultivated) area in the home gardens of the HHS from synthetic fertilizer were N= 0 .000708, P= 0.00015 and K = 0. 00058 kgm^2 respectively.

(B) <u>Amount of synthetic fertilizers replaced by the nutrients of compost</u>

During the monitoring period (26 weeks), a total of 3529kg of compost (whether homemade or purchased) was added to the cultivated areas of their lands by the HHS households. Therefore, the average addition of compost per unit cultivated area of HHS was 3529/20/500 = $0.350kgm^{-2}$. Total nutrients, the NPK added from application of compost was therefore N= 0. 00054, P= 0. 00189, K= 0.0059 kg m^{-2} (as calculated in the previous section).

Due to the practice of compost usage, a reduction in the use of chemical fertilizers is expected. The amount of synthetic fertilizers replaced by the nutrients of compost can be calculated as:

(Amount of synthetic fertilizer added per unit land * amount of particular nutrient provided by compost per unit land)/Amount of particular nutrients provided by synthetic fertilize per unit land

For N:= (0. 0059 * 0 .00054)/ 0.000708 = $0.0045kgm^{-2}$,
For P: = (0.0059 * 0.00189] /0. 00015 = $0.074kgm^{-2}$
For K: = (0.0059 * 0.0059) /0.00058 = 0.06 kgm^{-2}

If HHS had entirely depended on synthetic fertilizer without any compost usage over the monitoring period, the sample of HHS would have added the following amounts of nutrients to soil to satisfy the nutrient requirements. This could be equal to the amount synthetic fertilizer replaced per unit area * households (20)* average cultivated land per HHS.

Therefore, total nutrient requirement for total land with home gardens in the KUC area during the project monitoring period was 45.33kg for N, 745.5kg for P and 604.5kg for K. (n= 20).

In order to accommodate the above required elemental nutrient amounts the following quantities of K_2O, P_2O_5 and Urea would have been needed.

As per conversion factors used above, K_2O = 0.06/0.83 = 0.0723kg, P_2O_5 =0.074/0.436=0.170kg are required.

If single fertilizers had been used for provide t nutrients, the following quantities of fertilizers would have been used in the KUC over the project monitoring period by the HHS.

Approximately 46% of P_2O_5 is found in Superphosphate, (100/46) * 0.170= 0.370 kg. Therefor .370Kg Phosphate (P) would have been needed per m^{-2}, hence, 0.370x 500x 20 = 3700kg of superphosphate would have been required for the all HHS to grow their home gardens during 26 weeks of project monitoring period.

As approximately 60% of K_2O is found in muriate of potash, (100/60) * 0.0723= 0.121 kg. Therefore, .121Kg Potassium (K) would have been needed for m^{-2}, hence, 0.0723x 500x 20 = 72.3 kg of muriate of potash would have been required for the all HHS.

As approximately 46% of N is found in urea, (100/46) * 45...33= 98.55 kg. Therefore, 98.55Kg of Nitrogen (N) would have been needed for all HHS.

(C) <u>Amount of compost required to completely replace use of synthetic fertilizers</u>

Calculations were based on the following equation for elemental NPK nutrients.

(Amount of compost added per unit land * amount of particular nutrient provided by synthetic fertilizer per unit land)/ Amount of particular nutrient provided by compost per unit land

For N: = (0. 3261 * 0.000708)/ 0 .00054 = 0.471kgm^{-2},
For P: = (0.3261 * 0. 00036) / 0.00189 = 0.062 kgm^{-2}
For K: = (0.3261*0.000708) /0.0059 = 0.039kgm^{-2}

The required amount of compost to replace the nutrients that have added from synthetic fertilizers was 0.471 kgm^2. This amount satisfied the requirement of NPK added from synthetic fertilizers. With these estimations and assumptions, the requirement of compost need to replace the use of synthetic fertilizers completely, can identify by Nutrients per unit area* average area cultivated per HHS number of HH in sample. Which is (0.471 +0.3261) x 500 x 20 = 7971kg for the monitoring period. i.e. If another 4271Kg of compost had been used by the HHS it would have had the chance to omit the usage of synthetic fertilizers at KUC completely.

To generate this amount the KUC would have generated (6055x 4271)/ 1665 = 15532kg organic and agro-wastes by the 20 HH. To generate 4271Kg of compost, they may need (6055x 4271)/ 1665 = 15532kg organic and agro-wastes by the 20 HHS.

(D) <u>Calculation of the green house emission reductions</u>

If there were no compost utilized, the emission reductions (CO_2 equivalent) related to production and transport of urea 98.55kg + MOP 72.3 kg+ P 3700kg = 3870kg of the synthetic fertilizers. This replaced by the nutrients of the compost (due to compost use), calculated as follows using the values provided in Annexure 1.

Synthetic fertilizer brought from the factory to the distributer (25km distance) using a diesel 2MT lorry. Then the distributer used diesel van 2000 kg to compost transport for 3km distance. Hence the appropriate emissions related to transport can be calculated using the following estimates.

- Estimation of emissions during transport of 3870kg synthetic fertilizer is [(0.25* 3870kg fertilizer* 25km) + (0.32 *3870kg *3km) = 27902 kg of CO_2 equivalent.

- For production of 3870kg synthetic fertilizers, per kg of fertilizer, 5.88 kg of CO_2 equivalent emission released. Therefore, 3870kg, emissions estimated is = 22755kg, CO_2 equivalent. Thus the energy cost related to production and transport of the synthetic fertilizers is 27902+22755 = 50657kg CO2equi.

- Emission reductions related to production and transport of the synthetic fertilizers that were replaced by the compost in UPAF in KUC per unit land (*P*)is therefore=50657/20/500.=5.06 kg CO_2

Each household of HHS bought an average of 79.7 kg of compost for the monitoring period (Table 2). According to the field data, the volume of organic wastes needed to produce one kilogram of compost in the Kesbewa area, for the monitoring period was 3.66kg (6055/1655). Therefore, weight of organic waste required to replace bought compost was 3.66 * 1594= 5834.kg. This value is a collective value for 20 HHS. Therefore, waste required to produce the compost bought and used per unit area of land is = 5834 /500/20 = 0.58kgm^2

Households that did not practice home composting and gardening (HHC) had disposed 955.1 kg of waste unsorted organic and non-organic) during the monitoring period, via the urban council dump truck. The sample households (HHS) have disposed 725 kg of non-organic waste via the council dump truck which collects waste on once a week within the Kesbewa Urban Council limits. This indicates a less weight of waste collected by the HHS for disposal. Burning of waste had also been practice in the HHC as an alternative for disposing them through the Council Dump truck. Therefore, more weight could have been expected from HHC than HHS

The amount of waste used by the households for their own composting is (6055/20/500) =0.6kg m^2. Total waste required for production of compost per unit area of land is 0.58+ 0.6 =1.18 kg m^2.

The CO_2 emissions caused by fuel consumption for transport of waste (CO_2 equivalent per unit land area) that would have occurred if above wastes were sent to landfills at Karadiyanna, 3km away from project site, using 5MT diesel dump trucks *(q)* was (1.18kg * 3km*0.25) = 0.88 kg CO2equiv. The 0.25 is the emission estimate as per Annexure 1. And the emissions from landfills at Karadiyanna due to disposal of this amount of waste per unit land area (r)is 1.18kg*0.6 (as per annexure 1) = 0.69kg CO2equiv.

The energy use (CO_2 equivalent) for transport of bought compost for households at Kesbewa calculated as follows. Using the values obtained from field data Table 2, (1.594 ton bought compost amount *0.25 emission estimate as per annexure 1, *25km distance from factory to distributor) + (1.594 ton compost *3km distance* 0.32 distance from distributor to household) = 114.92tonn CO2equivduring transportation.

Values were calculated for the bought compost 1.594 ton, assumed that there had been field emissions of 0.0477 $CO_{2,}$ 0.0027 CO_2 during machine use for field applications, 0.0622 during production of compost, 0. 0062 emissions for collection of waste by truck and 0.434 emissions for machinery use for each tons of waste (Annexure 1).

As mentioned earlier, the volume of organic wastes needed to produce one kilogram of compost in the Kesbewa area was 3.66kg. Therefore, to produce 1594 kg compost, at least 5834 kg waste required. Or in other words, to produce 1.594 ton of compost, at least 5.834 ton waste had been required. Hence during compost production [(5834/1000)*(0.0477+0.0622+ 0.0027+0.0062+0.434)] =3.225kg CO_2 equal emission would have been released.

Therefore the Greenhouse Gas emission in production and transport of 1594kg of bought compost *(s)* had been 11492.74 + 3.225 = 11495.965kg $CO_{2.}$

The GHG energy emissions during transport of bought chemical fertilizer, 60kg (Table 2) used by the households was 432.6 kg CO2equiv, i. e. (60kg synthetic fertilizer* 0.25 emission estimate for 2MT lorry *25km distance from producer to distributor as per annexure 3) + (60kg fertilizer* 0.32 estimate for 2000kg lorry *3km distance to distributer to household as per annexure 3).

For production of that amount of fertilizer 352.8Kg CO2equiv was estimated. i.e. during production (60 *5.88* as per Annexure 1). In addition, emissions due to nitrogen fertilizer during application can also be considered. This estimates 292.2kg for the 60 kg used by the sample. (i.e. 60*4.87 as per annexure 1). This accounts for a total of 645kg CO2equiv. due to transport and use of 60kg of synthetic fertilizer by the HHS during the monitoring period.

If there were no composting at all, the requirement of synthetic fertilizers h (60+ 3870) kg distributed among the 20 households individually for there500 m^2 lands. Hence, the emission estimate had been 60+ 3870)/20/500= 0.393kgm^2. Field emissions for this amount would have been 0.00487 * 0.393 (as per Annexure 1) =0.0020tonn$CO_2m^{-2.}$

Due to application of compost and synthetic fertilizers, the actual emission calculated for both synthetic fertilizer and the compost.

(i.e. 0.002 kgCO_2 $m^{-2.}$ + [(60/20/500) * 0.00487(as per annex 3) + (3259/20/500) *0.0477(as per annex 3] = 0. 1570CO_2 m^{-2}

The difference in emissions with regard to application of compost over the synthetic fertilizers *(t)*:0.39-0.1570 =0.233 CO_2 $m^{-2.}$

Reduction emissions due to the reuse of organic wastes per land area for Kesbewa is= (p+ q+ r + t) - (S), i.e. (5.06+ 0.88+ 0.69+ 0...233)- 11495.965=-11489kg CO_2 m^{-2}

This amount accounts for 11489 CO_2 per m^2, and hence, the total cultivated area by the 20HHS had a total reduction of 500 x 11489 = 5744500kg CO_2. As one quarter of land of the HH was cultivated on average of, (50.39/4) x 1000= 12598kg CO_2 could have been reduced due to re-use of organic waste and home gardening.

VII. DISCUSSION

The study identified that the Households who have larger land engaged in home gardening in the KUC. Moreover, they tend to practice home composting using the organic fraction of the waste collected. The study also provided evidence for the reduction of the amount of waste collected by the KUC, contributing to the reduction of GHG emissions. Same as in KUC, municipal garbage collection (55 tons per day) was successfully reduced by recycling fresh organic waste for floriculture and home gardens in Gampaha, in which 300,000 permanent inhabitants have been reported (Amerasinghe, 2010). It is reported that in more urbanized areas waste being less reused or recycle.. Organic waste is usually buried, burned or left for the local authority cleaners to pick up

(Zon and Siriwardene, 2000). However, life Cycle Analysis Studies also have shown that fertiliser transport itself has very limited impacts on fossil energy use. Major benefits will probably stem from reducing waste volumes at landfill and disposal sites and reducing related waste transport needs.

According to calculations by IWMI (http://www.ruaf.org/sites/default/files/UAM23%20pag11-12.pdf), the amount of collected waste that could support food production if returned to urban and peri-urban areas in four African cities in Kumasi, Ghana, resulted in the following: In a "realistic" scenario, which only considered the waste currently collected (70-80-%of all waste produced), the entire N and P demand of (intra)urban farming could be covered, as well as 18 percent of the nitrogen and 25 percent of the phosphorus needs of peri-urban agriculture in a defined 40 km radius (Dreschel et al, 2007). So the collected organic waste can only support about 1/5 of the peri-urban derived production. When considering that 9% of the urban food demand is produced in urban areas and 40% in the peri-urban area; only 8% (1/5 of 40%) on top of the 9% urban production can be covered. This would mean that in total 17% of the food the city needs could be supported by nutrients in urban and peri-urban farming in Kumasi.

However, when composting, number of factors influence the rate of the process and the quality of the resulting compost:

1. Fragmenting organic (especially woody) material will increase its effectivity, and will thus increase the rate of composting.

2. The carbon to nitrogen (C/N) ratio of the composting material should be around 30:1. This can be achieved by mixing "green" plant material (e.g. grass, fruit, vegetable, weeds, etc.) and "dry" plant material (e.g. fallen leaves, straw, woody material, shredded paper and cardboard) in approximately equal amounts. A smell of ammonia during the composting process may indicate an excess of "green" material (rich in nitrogen). Some "dry" (carbon-rich) material can be added in this case to restore the balance (sawdust is very effective).

3. The moisture content of the composting material should be around 50%. When too wet("soggy") it will start to smell (H2S-production by anaerobic bacteria) and will decompose badly, and when it is too dry decomposition will be very slow.

4. For heat retention it is preferable to use a compost barrel, or a pile of at least 1m3. The optimum internal temperature for decomposition should be around 710°C.

5. The compost pile or contents of the barrel should be turned regularly (preferably daily), for aeration and to prevent overheating. However, this would require that no new material be added during the composting period (2–3 weeks), which is not practical for composting of household waste as a disposal method. When the contents of a compost barrel is not turned, new material can be added on top and compost can be extracted at the bottom (provided there is a hatch), but the composting process will take somewhat longer (4 weeks or more).

VIII. CONCLUSIONS

This study emphasis that reusing of organic fraction of wastes for composting and its subsequent use for urban and peri urban agriculture could be used as an indicator for reduction of GHG emissions. In this study KUC provided a good case study by reducing GHG emissions 11486kg CO_2 per square meter of cultivated land in home gardens in KUC.

Metropolitan, municipal and other local government institutions directly concerned with urban and regional planning and development will have the potential coordinating role in enhancing urban food security and city resilience by encouraging the households in home composting and home gardening or UPAF in support of local climate change adaptation and disaster risk reduction strategies. Such initiative is vital importance to a country like Sri Lanka, which is blessed with rich soil and a great diversity of fruits, vegetables, pulses and cereals.

REFERENCES

[1]. Amerasinghe P., Gammanpila U. Kodikara S., Ramanayake M., Developing Institutional Synergies for Effective Urban Agriculture Development in Sri Lanka, Urban Agriculture Magazine 25, 25-27, 2011.

[2]. Drescher T. W., Hagmann J., Chuma E. , Homegardens - a Neglected Potential for Food Security and Sustainable Land Management in the Communal Lands of Zimbabwe, Der Tropenlanclwit1, Beltrige zor Iropischen Landwirlsehafl ond Veterinarmedizin, 100. Jahrgang, Dktober99, S. 163 • 180, 1999.

[3]. Forbes M., W. Peter, F. Marina and H. Peter H, "Integrated solid waste management: a life cycle inventory" Blackwell Science Ltd, Malden, USA 2001.

[4]. Jagath N.K. M., Basnayake B. F. A., Nirosha K, Development of an integrated soild waste management system for three local authorities in Sri Lanka through

Capacity Mobilization. Tropical Agricultural Research Vol 14, 280-291, 2002.

[5]. Perera, K. L. S., "An overview of the issue of solid waste management in Sri Lanka" Proceedings of the 3rd International Conference on Environment and Health, Chennai, India, 15-17, 2003.

[6]. RUAF, Guidelines for monitoring the adaptation and mitigation impacts and co- benefits of UPAFactivities; Guideline 1- project Monitoring, Resource Centers on Urban Agriculture and Food Security (RUAF), 2013.

[7]. Visvanathan, C., "Domestic solid waste management in South Asia" 3 R South Asia Expert Workshop, Kathmandu, Nepal, 2006.

[8]. Wijetunge S., Community Views and Attitudes for Waste Management Improvement in a Higher Education Institute: Case Study Vol 1(1) 57- 69, 2013.

[9]. Zon L. V. , Siriwardene N., An Overview of Solid Waste Management in the Ja-Ela Area, Integrated Resources Management Programme in Wetlands (IRMP), Sri Lanka,Free University of Amsterdam, The Netherlands, 2000.