GSDR 2015 Brief

Urban Agriculture

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Related Sustainable Development Goals

Goal 01	End poverty in all its forms everywhere (1.1, 1.4, 1.5)
Goal 02	End hunger, achieve food security and improved nutrition and promote sustainable agriculture (2.1, 2.3, 2.4, 2.c)
Goal 12	Ensure sustainable consumption and production patterns (12.1, 12.2, 12.3, 12.4,12.5, 12.7, 12.8)
Goal 15	Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss (15.9)

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Introduction

Urban Agriculture (UA) and peri-urban agriculture can be defined as the growing, processing, and distribution of food and other products through plant cultivation and seldom raising livestock in and around cities for feeding local populations.[1 2] Over the last few years, UA has increased in popularity due to concerns about climate change and sustaining food security in urban areas.[3 4] The effects of climate change has induced crop reductions and affected optimal environmental growing conditions through rising temperatures and changes in rainfall patterns.[5, 6, 7, 8, 9] Although, agriculture contributes to 30% of anthropocentric greenhouse gas (GHG) emissions,[10] presence of vegetation in urban areas can lower temperatures and GHG emissions.[11] An environmental Life Cycle Assessment (LCA) of Urban Food Growing in London found urban farms could potentially reduce food-related GHGs, such as CO_2 by 34 tons per hectare.[12]

Increasing urban food deserts in many parts of the world has motivated the improvement of methods of UA in order to complement urban food needs.[13 14] In this paper, UA was categorized into two spheres: Controlled Environment Agriculture (CEA) [15] and Uncontrolled Environment Agriculture or open space agriculture (UEA).[16]

Examples of UEA include community gardens, vegetable gardens and rooftop farms, which exist worldwide and are playing important roles in the urban food systems.[17] CEA includes any form of agriculture where environmental conditions (such as, light, temperature, humidity, radiation and nutrient cycling) are controlled in conjunction with urban architecture or green infrastructure.[18] Methods of CEA discussed are zero-acreage farming (Z-farming), greenhouses and vertical farming/ skyfarming.[19,20, 21]

FACTS & FIGURES

- UA includes small to large areas within or around cities: vacant lots, community garden, balconies, rooftop farms, indoor farms and greenhouses.[i]
- Presently, more than 800 million people worldwide practice UA, including over 20 million people in West Africa.[ii]
- UA is located in close proximity to populous regions.[iii]
- Plant-based and livestock produces 30% of GHG emissions.[iv]

Examining these new methods contributes to addressing potential urban food insecurity because by 2050, 60% of the world's population will live in cities which will increase demand of resources.[22] Ultimately, interest in transforming urban food systems is an integral part of a sustainable development path for cities. Therefore, in this paper both CEA and UAE were examined in terms food production potential, risks and benefits.

Scientific debate

Since 1990s, the scientific debate encompassing UA focus on competition for non-renewable resources (i.e., soil, water, land) and its economic viability. UA is taking advantages where Rural Agriculture (RA), the primary producer of food in cities, failed to achieve urban food security. It complements RA in terms of self-provisioning, marketing flows and market supply flows.[23] Also, there is a growing concern that RA will deprive lands (through land grabbing) from rural populations and trigger its movement toward cities thereby reducing rural populations.[24] However, UA is unlikely to turn any city or most households fully self-sufficient in all of the food which they may require.[25]

The major challenges in UA are determining how to monitor, control, and reduce risks in the physical, economic and social environment; and understanding how UA can be a sustainable component of the global urban food systems.[26] While opponents highlight the negative impacts of UA, related to health risks, productivity and pollution, proponents counter these sentiments by emphasizing the viability of UA in terms of increasing the locality of food and reduction of energy expenditure in production.[27] [28]

Opponents of UEA, caution the excessive use of inputs with high levels of nitrogen, phosphorous and raw organic matter with heavy metals.[29] [30] For example excessive nutrient inputs to the livestock unit and poor handling of manure [31] can lead to environmental issues in the long run. Other problems that urban dwellers may face are: air pollution (from emissions of carbon dioxide, methane, ammonium, nitrous oxide, nitrogen oxide, etc.), odor nuisance, overuse of chemical spray**,** Zoonotic diseases, veterinary public health issues from livestock, and cumulative negative effects because of no legal controls of UA.[32] Composting another technique used to recycle organic waste in UEA can restore contaminated soils and biodiversity of soil organisms.[33] In aquaculture for example, the use of water for recirculation, commercial feed, and drugs can lead to excess nutrients and organic matter, which will enhance the proliferation of microorganisms, such as, heterotrophic bacteria.[34]

The proponents of UEA are exploring new solutions to address these risks. One example is an improved management of manure which enhance cattle productivity and provides nutrients for urban agriculture in Niamey, Niger [35] Another example is treated wastewater reuse for irrigation,[36] a treatment system (Appendix 7) consisting of a waste stabilization pond (WSP) and a constructed wetland (CW) system connected to it. This case showed that with the integration of the treatment technologies and proper operation of systems, recycled water with significant amounts of nutrients can be made available for farming, in turn reducing the rate of fertilizer application.[37] This system also reduces the pollutant load in the surrounding environment.[38] Those proponents are positive that there are many ways to make urban agriculture environmentally friendly and viable.

FOOD FOR THOUGHT

- UA would require roughly one third of the total global urban area to meet the global vegetable consumption of urban dwellers based on the current space constraint.[vi]
- 60% of the world population will live in urban areas by 2050.[vii]
- Safe use of waste water can provide the needed water, nitrogen, and phosphorus for growing food. [viii]

A few concerns of the same concerns also arise in CEA methods. Table 4, examines the main inputs, application, risks and benefits of CEA methods and UEA method.[39,40,41,42,43,44] CEA is based on the use of hydroponic or water-based nutrient rich solutions as a substitute for soil. Additional water inputs are considered energy intensive, proponents show aqueous water recycling systems conserve water and decrease building water bills. [45,46,47] In terms of energy saving, green rooftops, which can also be integrated in CEA was found to regulate temperatures building temperatures in New York City.[48] Rooftop gardens also use 75% less water than conventional farms. [49]

Skyfarms are more energy efficient in the production staple cereal crops, which make up the majority of global food consumption.[50 51 52] The scale of Z-farming prospected for integration with current urban food markets, although some small-scale examples are utilized at the private level [53]. Another intensive input is artificial light-emitting diode (LED) to mimic photosynthetic processes of natural sunlight in seasons of limited sunlight.[54,55,56,57,58,59] Researchers are working to improve LED efficiency in CEA approaches. [60]

Studies show increased plant transpiration stores excess water in plant leaves, reducing photosynthesis, which inhibits plant growth. [61,62,63] Increased transpiration potentially set optimal environments for viruses and fungi which can infect plants and also pose threats to humans.[64,65,66] To address this CEA systems incorporating dehumidification processes through natural ventilation are being implemented to mitigate increased transpiration.[67] Comparatively, in greenhouse agricultural methods glass panes function as natural dehumidifiers.[68]

The main concern with CEA methods is capital intensity, for instance, over 30 years the fixed cost for equipment and a 37 story building for a vertical farm is estimated at $248 million. [69] Though projected agricultural productivity investments of US$2000 million annually are projected for additional expenditure offset the negative impacts of climate change on nutrition.[70] Other CEA methods can be applied to current building, lower story buildings and smaller spaces, so costs are significantly less. Countries in South Asia are expected to experience significant increases in crop reduction due to climate change,[71] Singapore is investing in vertical farming to feed growing urban populations [72 73].

Overall, potential returns of CEA are higher crop yields than conventional agriculture for certain such as, carrots, radish, potatoes, pepper, tomatoes, strawberry, peas, cabbage, lettuce and spinach.[74] Also multiple precedents of CEA exist in both the Global North and Global South.[75] For example, a vertical farm in South Korea stands at three-stories and a recent prototype estimates a building with 27 floors could provide food to 15,000 residents.[76] Z-farming, exists in major cities of North America, Europe, Asia and Australia.[77]

The efficiency of UA will differ in developed and developing countries,[78] however when applied efficiently, UA can increase the access, availability and distribution of food.[79] [80] The importance of the following factors in different geographic areas may impact urban agricultural activities: competition for resources (land, water, labor, energy); financial support from private or public sector; horticulture techniques: production of vegetables; productive use of under-utilized resources; low input processing and storage techniques with micro-credit support. Taking those factors into consideration will help make urban agriculture sustainable.[81,82,83]

It is important for practitioners and other actors in the urban environment to understand that UA can participate in efficient competition of resources if strategies are developed to enhance potential environmental benefits, minimize problems, and find ways to secure practitioner access to land need comprehensive assessments. Some optimal management practices (Appendix 6) [84] such as land use planning will benefit from hydrological functioning through soil and water (i.e. rainwater) conservation, micro-climate, biodiversity. These mechanisms assist cities in avoiding cost of disposal of recycled urban waste, and provide greater recreational and aesthetic values of green space.[85] For example, macrophytes can be used to clean water and feed chicken and fish, and small scale irrigation and Drip irrigation.[86] Moreover, the sustainability of UA is enhanced by some advantages including the improvement of community food security, the provision of educational facilities, linking consumers to food production, serving as a design inspiration enhance its sustainability, and the reduction of building energy costs by acting as a cooling effect in the summer and insulation in the winter.[87]

Goals

In recognition of the SDGs, UA (encompassing both UEA and CEA) can assist in potentially decreasing hunger and poverty (SDG 1.1,1.4,1.5, 2.1, 2.3, 2.4, 2.c); creating sustainable food production patterns (12.1, 12.2, 12.3, 12.4, 12.5, 12.6, 12.7,12.8,15.9) and promoting the integration of environmental values in development (SDG 15.9). In terms of decreasing poverty and hunger, UA provides a mechanism for improving urban food security and providing entrepreneurship opportunities for low-income individuals. In creating sustainable food patterns, UA is projected to reduce climate change-related greenhouse gas emissions through reducing food production and distribution inputs. Furthermore, by incorporating waste management, nutrient recycling and energy recycling UA utilizes environmentally sustainable practices in meeting the necessities of urban regions.

Recommendations/Targets

The significance of UA and corresponding discourse on its risk and benefits show the efficiency of UA will differ in developed and developing countries.[88] Therefore, the implementation of UA to develop safe and nutritionally adequate food systems and sustainability of the urban environment will depend on the following recommendations for future agendas:

- **Research and Education:** The recognition of research and science on UA in both developed and developing countries at the biological, social and political levels, could support integration of urban and rural food supply systems[89] and recourse the current intersections between climate change, food security and sustainable food production. Funding in this area also enhances technical expertise on UA.

- **Policy:** Coherent management policies for UA set environmentally sustainable requirements or standards for cropping techniques, convenient treatment of urban water and solid waste· Development of food policies optimizing UA through contracting systems with conventional or rural agriculture practices replaces the perception that UA could replace global food production.[90] Also, policies on global food waste[91] can also highlight some areas where UA can be most feasible.

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Appendix 1: Research methods

Urban agriculture (UA) was selected for this brief because of the author's personal interests and previous experiences working on UA projects in both the Global North and South to address local food security and local food system support. UA is an emerging area of science to address increasing food access in global cities in light of climate change.

The methodological framework for this brief is already mentioned in the preface. For this particular topic scientific peer-reviewed articles from journals in biological, environmental, social, economic, public health and physical sciences were examined to understand related scientific credibility and debates. Under further analysis, one of the largest scientific peer-reviewed article database, SCOPUS, was used to measure the frequency of scientific articles in UA from 1975-2014 and in each emerging UA mechanism from 2009-2014 via article title, abstract and keyword. Articles related to UA and climate has increased from 1975 with steady growth between 2005-2010 and recent surges over the past two years.

The share of research on UA is dispersed in both the Global North and South: 18.9 % for Africa, 35% for America, 34.5% for Europe, and Asia: 11 % .The following number of articles was found for each topic building integrated agriculture (5); vertical farming (17); skyfarming (1); Z Farming or zero acreage farming (2); controlled environment agriculture (33) and urban agriculture and climate change (37). Authors of these articles represented the following countries: the USA, China, Germany, Italy, Austria, Mexico, France, Canada, Indonesia, Australia and the United Kingdom.

Interviews from three experts in the field of UA were also conducted to verify the credibility of the criteria selected for UA, the relevance of UA to achieving sustainable development and reviewing current discourse surrounding UA (Table 1).

Figure 1. The frequency of UA articles from 1975 to 2014 using Scopus and Science Direct.

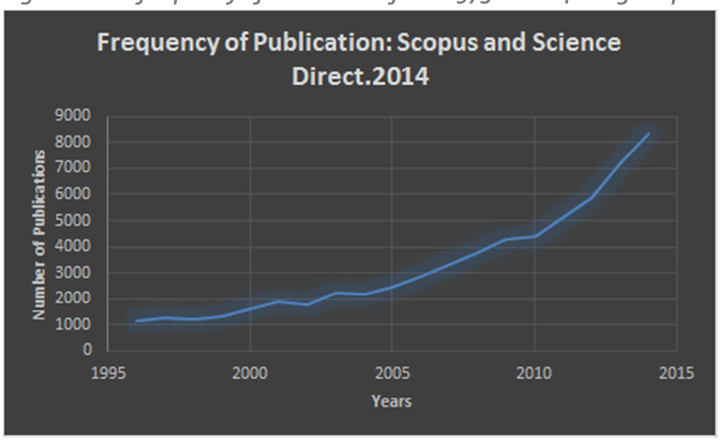

Table 1. UA experts qualifications and corresponding interview codes used in brief.

Interview Code	Experts Qualifications
001	Dickson Despommier Professor in the Department of Environmental Health Sciences, Columbia University Director of the Vertical Farm Project Interviewed, December 4, 2014
002	Federico Martellozzo Post-Doctoral Fellow University of Rome La Sapienza MEMOTEF - Dept. of Methods and Models for Economics, Territory and Finance Interviewed, December 11, 2014
003	Isidor Wallimann, Ph.D. Professor Emeritus Visiting Research Professor, Maxwell School, Syracuse University Founder of Urban Agriculture Basel Interviewed December 11, 2014

Appendix 2: Most Common Forms of UA surveyed in some US cities

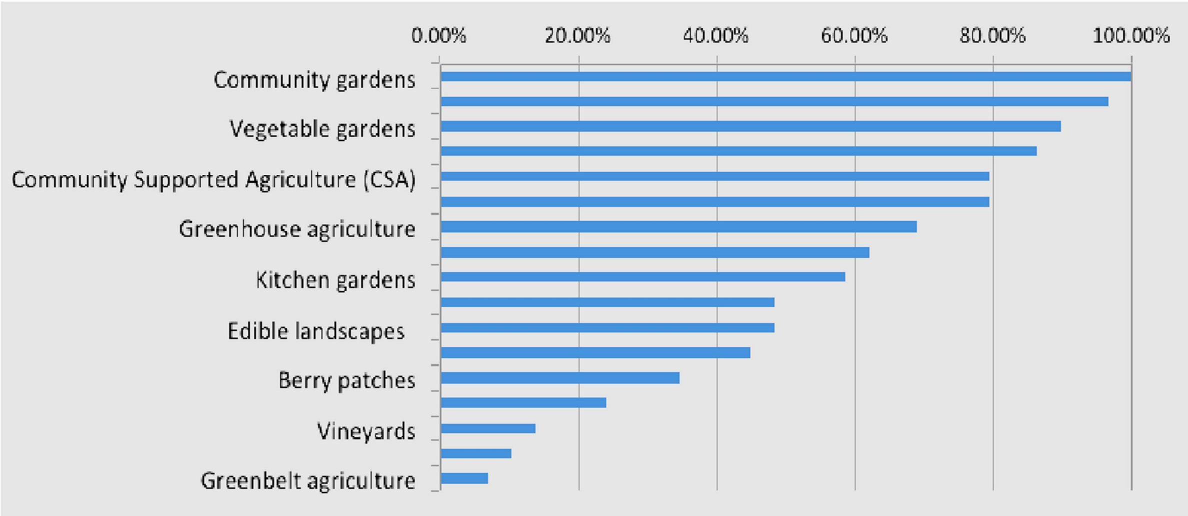

Figure 2. Most Common Forms of UA surveyed in some US cities (Hendrickson & Porth, 2012)

Appendix 3: Comparative analysis of UA and RA

Table 2. Comparative Analysis of UA and RA (Data Retrieved from: Mougeot, 2000)

	UA	RA
Scale of Production	Mostly small	Mostly Large
Marketing System	Higher percentage of producers	Higher levels of Trade
Alternatives available	Variable	Limited
Farm to Market System	Proximity to more people	Far from cities

Appendix 4: Opportunities and risks of urban agriculture

Table 3. Opportunities and risks of urban agriculture (Data retrieved from: Hendrickson & Porth, 2012)

Opportunities for urban areas (in opposition to RA)	**Risks for urban areas**
Physical Environment	
▪ Less need for packaging, storage, and transportation ▪ Proximity to services, including waste treatment facilities ▪ Waste recycling and re-use possibilities	▪ Increased competition for land, water, energy, and labor ▪ Reduced environmental capacity for pollution absorption ▪ High levels of air pollutants in cities and microbial contamination of soil and water
Economic Environment	
▪ Potential Agricultural jobs with low barriers to entry ▪ Non-market access to food	▪ Limited Production Quantity ▪ Varied seasonal Production Quality
Social Environment	

▪ Availability of fresh fruits and vegetables ▪ Community Bonding ▪ Access to green spaces ▪ Emergency food supplies ▪ Soil treatment ▪ Environmental stewardship	▪ Environmental and health risks from inappropriate overuse of pesticides and fossil-fuel based fertilizers

Appendix 5: Comparative Analysis of UA Methods in CEA and UAE

Table 4. Comparative Analysis of UA Methods in CEA and UAE (Data Retrieved from: Germer et al., 2011; Thormaier, 2014; Despommier, 2013; Despommier, 2011, and Specht et al., 2014)

	UA Methods	
	UEA (open space, rooftops farms)	**CEA (Z-farming, Greenhouses, vertical farms, skyfarms, rooftop farms)**
Main Inputs	Low Fertilizer Organic Soil	Fertilizers Pesticides Natural light (seasonal) Artificial light Water-based growing solutions *Greenhouses: low fertilizer input, organic (UEA), soil (seldom)
Application	Urban Peri- urban Small-large scale Use of macrophytes to clean water and feed fish *Medium-large scale: Z-farming & vertical farms *Rural: Greenhouses	
Major Risks	Exposure to pollutants **Open space: uptake of soil-based heavy metals; human and animal manure	High energy inputs Artificial fertilizers, Capital intensive, Non-labor intensive **Vertical farms: plant viruses and disease; high energy inputs
Major Benefits	Storm water management Absorption of solar energy Compost organic waste Meet organic requirements	High crop yields Recycle organic waste

Appendix 6: Cattle Productivity with an improved manure management system

Diogo R., et al.(2013) showed the effect of current cattle feeding (So) and improved cattle feeding (S1) and manure management (S2) on indicators of livestock productivity (annual milk offtake and annual body weight (BW) change), recycled manure dry matter (DM), and nitrogen (N), phosphorus (P) and potassium (K) in three different urban and peri-urban farm types of Niamey, Niger. All values are in kg per animal and year.

Farm type	AH						AH+G						AH+G+M					
Indicator	Cattle			Manure harvested			Cattle			Manure harvested			Cattle			Manure harvested		
	Milk	BW	DM	N	P	K	Milk	BW	DM	N	P	K	Milk	BW	DM	N	P	K
Urban																		
S0	0	19.3	338$^{b,\alpha}$	9.49$^{b,\alpha}$	1.40$^{b,\alpha}$	5.24$^{a,\alpha}$	0	0	178$^{b,\beta}$	3.65$^{b,\beta}$	0.52$^{b,\beta}$	2.61$^{a,\beta}$	0	34.8	354$^{b,\alpha}$	9.89$^{b,\alpha}$	1.44$^{b,\alpha}$	5.29$^{ab,\alpha}$
S1	1423	49.6					706	24.1					1423	49.6				
S2_1	-“-	-“-	450$^{b,\alpha}$	12.62$^{b,\alpha}$	1.86$^{bc,\alpha}$	5.88$^{a,\alpha}$	-“-	-“-	221$^{b,\beta}$	4.56$^{b,\beta}$	0.67$^{ab,\beta}$	3.32$^{a,\beta}$	-“-	-“-	470$^{b,\alpha}$	13.15$^{b,\alpha}$	1.92$^{bc,\alpha}$	5.61$^{a,\alpha}$
S2_2	-“-	-“-	642$^{a,\alpha}$	20.51$^{a,\alpha}$	2.30$^{ac,\alpha}$	4.00$^{b,\alpha}$	-“-	-“-	307$^{ab,\beta}$	7.88$^{ab,\beta}$	0.80$^{ab,\beta}$	1.95$^{bc,\beta}$	-“-	-“-	645$^{a,\alpha}$	21.39$^{a,\alpha}$	2.40$^{ac,\alpha}$	4.18$^{b,\alpha}$
S2_3	-“-	-“-	691$^{a,\alpha}$	21.19$^{a,\alpha}$	2.40$^{a,\alpha}$	5.25$^{a,\alpha}$	-“-	-“-	409$^{a,\beta}$	10.11$^{a,\beta}$	1.02$^{a,\beta}$	2.54$^{ab,\beta}$	-“-	-“-	690$^{a,\alpha}$	22.13$^{a,\alpha}$	2.48$^{a,\alpha}$	5.50$^{ac,\alpha}$
Peri-urban																		
S0	0	−23.2	163^{b}	3.36^{b}	0.49$^{b,\beta}$	2.32$^{ab,\beta}$	1217	−22.2	211^{b}	4.96^{b}	0.77^{b}	3.07^{ab}	614	19.7	250^{b}	6.20^{b}	0.93$^{b,\alpha}$	3.75$^{a,\alpha}$
S1	428	24.1					1423	24.6					1423	34.6				
S2_1	-“-	-“-	197$^{b,\beta}$	4.32$^{b,\beta}$	0.63$^{b,\beta}$	2.95$^{a,\beta}$	-“-	-“-	262^{b}	6.38^{b}	0.99$^{bc,\alpha}$	3.76$^{a,\alpha}$	-“-	-“-	321$^{b,\alpha}$	8.24$^{b,\alpha}$	1.24$^{bc,\alpha}$	3.85$^{a,\alpha}$
S2_2	-“-	-“-	291$^{a,\beta}$	7.43$^{a,\beta}$	0.78$^{ab,\beta}$	1.80$^{b,\beta}$	-“-	-“-	389$^{a,\alpha}$	11.30$^{a,\alpha}$	1.26$^{ab,\alpha}$	2.40^{b}	-“-	-“-	477$^{a,\alpha}$	13.39$^{a,\alpha}$	1.53$^{ac,\alpha}$	2.96$^{b,\alpha}$
S2_3	-“-	-“-	373$^{a,\beta}$	9.88$^{a,\beta}$	1.03$^{a,\beta}$	2.29$^{ab,\beta}$	-“-	-“-	479$^{a,\alpha}$	13.83$^{a,\alpha}$	1.56$^{a,\alpha}$	3.05$^{ab,\beta}$	-“-	-“-	517$^{a,\alpha}$	13.81$^{a,\alpha}$	1.61$^{a,\alpha}$	3.89$^{a,\alpha}$

Farm types: AH = animal husbandry alone; AH+G = animal husbandry + gardening; AH+G+M = animal husbandry+ gardening + millet cultivation. Within farms, different Roman letters indicate significant differences (P 6 0.05) between scenarios for DM, N, P, and K. Within a scenario, different Greek letters indicate significant differences (P 6 0.05) between farm types. Where no letters are given, the respective differences are insignificant. The average number of adult animals per year present under So on urban farms were 2 (AH), 0.75 (AH+G) and 0.75 (AH+G+M), as opposed to 1.5 (AH), 1.33 (AH+G) and 4.67 (AH+G+M) on peri-urban farms.

Scenario description:

- So: Baseline: grazing, indiscriminate supplementation, open air manure storage.
- S1: Improved feeding: grazing, adjusted supplementation, open air manure storage.
- S2_1: Improved feeding as under S1 plus improved manure collection: shorter manure collection time (open air manure storage).
- S2_2: Improved feeding as under S1 plus improved manure storage: covered manure heap.
- S2_3: Improved feeding as under S1 plus improved manure collection and storage: shorter manure collection time and cover manure heap.

They concluded that the combination with shortened manure collection intervals and low-cost covering of the manure heap may reduce negative environmental externalities at the same time, and allows recycling substantial amounts of nutrients to cropland and vegetable gardens. And, the resulting crop yield increases should also increase monetary revenues from sales of products, and the same applies to the livestock unit.

Appendix 7

The WSP has a design capacity of 4500 m3/d and consists of anaerobic pond, two facultative ponds and six maturation ponds. The facultative ponds are arranged in parallel while the maturation ponds are connected in series (Fig1). The CW has a capacity of 200 m3/day and it receives effluent from the WSP at the maturation pond 2 and runs parallel to the remaining four maturation ponds (Fig. 1).

The CW treats the partially treated waste water so the effluent from it gets treated by both the treatment systems (WSP-CW) while major portion of the wastewater gets treated through the WSP only. The final effluent is discharged to the irrigation channel via a fishpond located on the downstream. The monthly average inflow to the WSP during the study time was 4192.5m3/d and that of the CW was about 200 m3/d. The outflows were estimated to be 2452.6 m3/d and 134 m3/d for the WSP and CW respectively. The effluent from the treatment works is used for irrigating mainly paddy farms. The total land irrigated is 121,405 m2 and it benefits about 60 famers. The WSP-CW effluent irrigates 8094 m2 and WSP effluent irrigates the rest of the area. Paddy is grown twice in each year on farms plots of sizes ranging from 1619 to 3035 m2 each and the production is about 3750–7500 kg per hectare. Apart from paddy some other crops such as maize, pumpkins, beans, potatoes and vegetable (tomatoes, spinach, and amaranths), are also grown in additional land using the treated effluent. In high demand season (planting to ripening) almost all of the treated effluent is used for irrigation, while in low demand season (nearly harvesting time) only some of the treated effluent is used for irrigation. The excess flow in low demand period is discharged to the stream which is downstream the irrigated area.

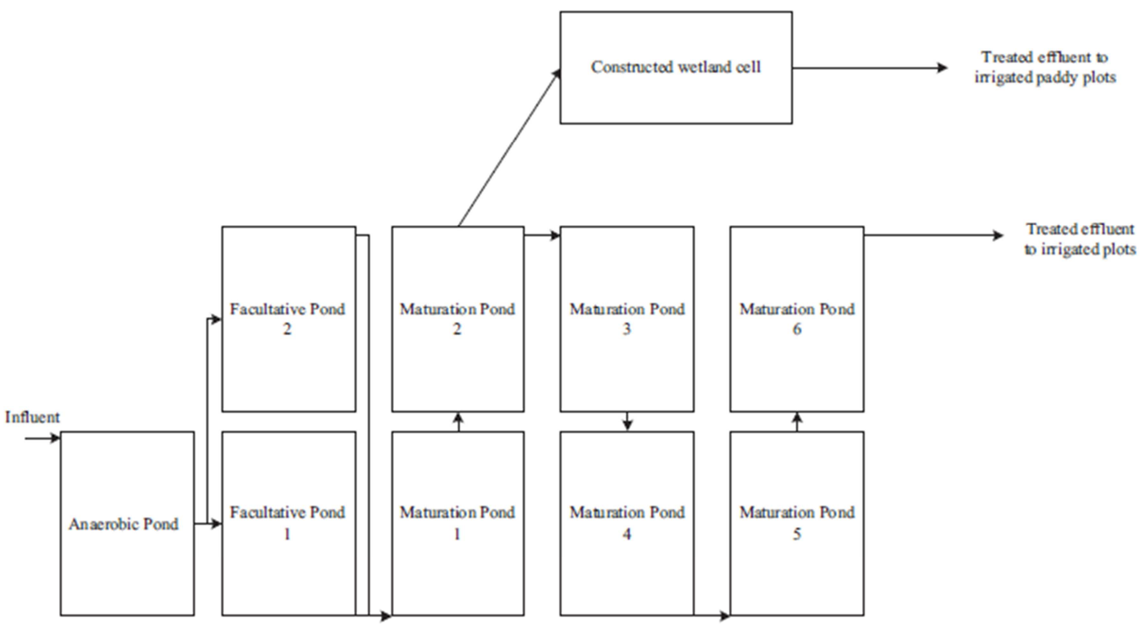

Figure 1. The Moshi wastewater treatment schematic layout

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