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Urban and peri-urban agricultural production along railway tracks: a case study from the Mumbai Metropolitan Region

Prem Jose Vazhacharickal [a], Martina Predotova [a], Dornadula Chandrasekharam [b], Sharit Bhowmik [c], Andreas Buerkert [a,*]

[a] *Organic Plant Production & Agroecosystems Research in the Tropics and Subtropics, University of Kassel, Germany*
[b] *Department of Earth Sciences, Indian Institute of Technology Bombay, Mumbai, India*
[c] *School of Migration and Labour Studies, Tata Institute of Social Sciences Mumbai, India*

Abstract

Urban and peri-urban agriculture (UPA) contributes to food security, serves as an opportunity for income generation, and provides recreational services to urban citizens. With a population of 21 Million people, of which 60 % live in slums, UPA activities can play a crucial role in supporting people's livelihoods in Mumbai Metropolitan Region (MMR). This study was conducted to characterize the railway gardens, determine their role in UPA production, and assess potential risks. It comprises a baseline survey among 38 railway gardeners across MMR characterized by different demographic, socio-economic, migratory, and labour characteristics. Soil, irrigation water, and plant samples were analyzed for nutrients, heavy metals, and microbial load. All the railway gardeners practiced agriculture as a primary source of income and cultivated seasonal vegetables such as lady's finger (*Abelmoschus esculentus* L. Moench), spinach (*Spinacia oleracea* L.), red amaranth (*Amaranthus cruentus* L.), and white radish (*Raphanus sativus* var. *longipinnatus*) which were irrigated with waste water. This irrigation water was loaded with 7–28 mg $N\,l^{-1}$, 0.3–7 mg $P\,l^{-1}$, and 8–32 mg $K\,l^{-1}$, but also contained heavy metals such as lead (0.02–0.06 mg $Pb\,l^{-1}$), cadmium (0.03–0.17 mg $Cd\,l^{-1}$), mercury (0.001–0.005 mg $Hg\,l^{-1}$), and pathogens such as *Escherichia coli* (1,100 most probable number per 100 ml). Levels of heavy metals exceeded the critical thresholds in surface soils (Cr, Ni, and Sr) and produce (Pb, Cd, and Sr). The railway garden production systems can substantially foster employment and reduce economic deprivation of urban poor particularly slum dwellers and migrant people. However this production system may also cause possible health risks to producers and consumers.

Keywords: baseline survey, health risks, heavy metals, wastewater use

1 Introduction

Urban and peri-urban agriculture (UPA) comprises the production, processing and a marketing of food and plant/animal based products including ornamental flowers, fibres, and fuel dispersed in urban and peri-urban areas, typically applying intensive management on scarce lands (Bryld, 2003; Drechsel *et al.*, 2007; Pearson *et al.*, 2010). The contribution of UPA to urban livelihood strategies has often being stressed, including waste recycling, better space utilization, employment, income generation, and food security of often poor population groups, especially in developing countries (Obuobie *et al.*, 2006; Hill *et al.*, 2007; Graefe *et al.*, 2008; Sinha, 2009; Gerster-Bentaya, 2013). UPA production systems may reduce the ecological foot print of the cities and allow for synergies between urban domestic and in-

* Corresponding author
Email: tropcrops@uni-kassel.de

dustrial sectors with agriculture (Midmore & Jansen, 2003; De Zeeuw *et al.*, 2011). Population explosion and migration of people towards urban areas enhance the pressure on food, shelter, water, and basic necessities (Cohen, 2006). Migration from rural area to urban area is a common phenomenon in developing countries, where people seek for better employment, education, services, and income.

Mumbai, known as the commercial capital of India, is a heavily populated industrial city whose population in 2009 reached 21 million, thus becoming the fourth largest urban agglomeration in the world (Krishna & Govil, 2005; UN, 2010; Jain *et al.*, 2013). In the Mumbai Metropolitan Region (MMR) the Indian Railways (central, western and harbour lines) play an important role in UPA production. Under the scheme "Grow more food", the Indian Railway companies rented since 1975 unutilized land near railway tracks and stations to railway class IV employees and non railway employees for promoting the cultivation of vegetables and to secure and to beautify and protect the railway land against encroachment from slum dwellers (Indian Railways, 2008). In the MMR, about 176 ha of land (yearly rent of 309 US$ per ha; 1 US$ equivalent to 45 Indian Rupee) were allotted among 282 railway employees (personal communication 2011, Indian Railways). Subletting of the land by railway class IV employees to migrant people from Uttar Pradesh and Madhya Pradesh is common practice who transformed this land to productive railway gardens by growing vegetables such as Lady's finger/Okra (*Abelmoschus esculentus* L. Moench), Spinach (*Spinacia oleracea* L.), Red amaranth (*Amaranthus cruentus* L.), and Taro (*Colocasia esculenta* L.) (Figure 1, Table 1). These migrant farmers stay in temporarily made shelters in the railway gardens with their families or with railway garden workers without any basic amenities. Based on the application of fertilizers, manure and pesticides, railway gardens are high input production systems and many face serious problems such as wastewater usage and soil contamination due to domestic and industrial wastes. But knowledge of agro-ecological and socio-economic characteristics as well as their impact on the productivity and sustainability of railway garden production systems is still scarce. We therefore conducted a baseline survey with the purpose of (1) identifying and characterising the households involved in the cultivation, (2) determining present garden management practices and marketing of produce and (3) assessing the status quo of heavy metal contamination in soil, produce, and irrigation water in these systems.

2 Materials and methods

2.1 Study area

The MMR consists of eight Municipal Corporations (Greater Mumbai, Thane, Kalyan-Dombivali, Vasi-Virar, Navi Mumbai, Mira-Bhayandar, Bhiwandi-Nizampur, and Ulhasnagar) and nine Municipal Councils (Alibag, Ambernath, Karjat, Khopoli, Kulgaon Badlapur, Matheran, Panvel, Pen, and Uran) covering an area of 4,355 km^2 with a population density of 4,065 per km^2 (MMRDA, 2010) and spread across four Districts (Mumbai city, Mumbai sub-urban, Thane, and Raigad).

This study was conducted from July 2010 to January 2011 along the Western, Central, and Harbour lines of the Indian Railways. Average annual rainfall in MMR amounts 2,642 mm and mean annual temperature is 26.8°C (averages from 1955–2005; Regional Meteorological Centre Mumbai, 2010). Maximum rainfall occurs from June to September mainly due to the South West Monsoon and temperatures are highest in May and November. In 1971 the total agricultural area of MMR was 2,098 km^2 that was reduced to 1,446 km^2 in 1991 (Acharya, 2004).

2.2 Survey design and data collection

Google Earth images from DigitalGlobe Quickbird with a resolution of 0.6 m per pixel (Google Inc, California, USA) and land-use maps (Landsat L7 ETM+, USGS) were used to track the area of agricultural production in MMR and to separate railway garden production systems. Semi-structured questionnaires were used to cover demographic, socio-economic, migratory, and labour characteristics. Thirty eight farmers cultivating railway gardens were selected from different regions distributed along railway tracks using a snowball sampling technique (Figure 2). The face-to-face interviews were conducted with the household heads and locations of the railway gardens were recorded with the help of a Trimble Geoexplorer II GPS (Trimble Navigation Ltd, Sunnyvale, CA, USA). The questionnaire was carried out from July 2010 to December 2010 and focused on households located along the Western, Central, and Harbour railway lines.

Irrigation water samples (n=8) from open sewer tunnel/field and soil samples (n=4) were taken at various points in the 38 railway gardens and tested for nutrients nitrate (NO_3-N), ammonium (NH_4-N), phosphorus (P) and potassium (K) and the heavy metals lead (Pb), cadmium (Cd), arsenic (As), and mercury (Hg). Irrigation water samples were tested additionally for the micro-organisms *Escherichia coli*, *Vibrio* sp., *Salmonella* sp.,

Fig. 1: *Two examples of railway garden production systems from the Western and Central railway lines in the Mumbai Metropolitan Region, India: (Left) a garden with Amaranthus cruentus L. and (Right) a garden with Abelmoschus esculentus L. Moench.*

Table 1: *Vegetables cultivated in UPA railway gardens of the Mumbai Metropolitan Region, India.*

Serial No	*Common name (English)*	*Local name (Hindi)*	*Botanical name*
1	Lady's finger/Okra	Bhindi	*Abelmoschus esculentus* L. Moench
2	Spinach	Palak	*Spinacia oleracea* L.
3	Red amaranth	Lal Maat	*Amaranthus cruentus* L.
4	Fenugreek	Methi	*Trigonella foenum-graecum* L.
5	White radish	Mula	*Raphanus sativus* var. *longipinnatus*
6	Malabar spinach	Mayalu	*Basella alba* L.
7	Green amaranth	Chawli	*Amaranthus tritis*
8	Sorrel leaves	Ambaadi	*Hibiscus sabdariffa* L.
9	Taro	Alu	*Colocasia esculenta* L.
10	Dill	Shepu	*Anetthum graveolens* L.

and coliform bacteria. At particular sites we also collected representative samples of produce and determined their concentrations of Pb, copper (Cu), zinc (Zn), Cd, As, and Hg. All samples were taken from November 2010 to January 2011.

2.3 Irrigation water samples

The irrigation water samples were taken with a 250 ml Polyethylene (PE) bottle either directly from the source (open sewer tunnel) or from the field and were acidified with two to three drops of concentrated HCl (32 % w/v) to prevent microbial growth and settling of dissolved heavy metals. For microbiological examinations, sterile, pre-autoclaved glass bottles were used and samples were collected leaving some empty space between cap and top level. Total coliforms were counted using the Multiple Tube Dilution Technique (MTDT) with three tube dilution (APHA, 2005). The isolation of *Vibrio* sp. was done using thiosulfate citrate bile salt (TCBS) agar and the isolation of *Salmonella* sp. by xylose lysine deoxycholate (XLD) agar (Himedia, Mumbai, India) using standard microbiological protocols (Ayres & Mara, 1996). Heavy metals in irrigation water were analyzed by Atomic Absorption Spectroscopy (PinAAcle 900F, PerkinElmer Inc., Waltham, MA, USA).

2.4 Soil samples

Soil samples were air dried for three days and crushed using a ceramic mortar and pestle. The organic debris from the samples was removed and sieved at 2 mm. All samples were analysed for pH, moisture factor (MF), water content (WC), soil organic matter (SOM), electrical conductivity (EC), potassium (K), sodium (Na), calcium (Ca), magnesium (Mg), phosphorus (P), total ni-

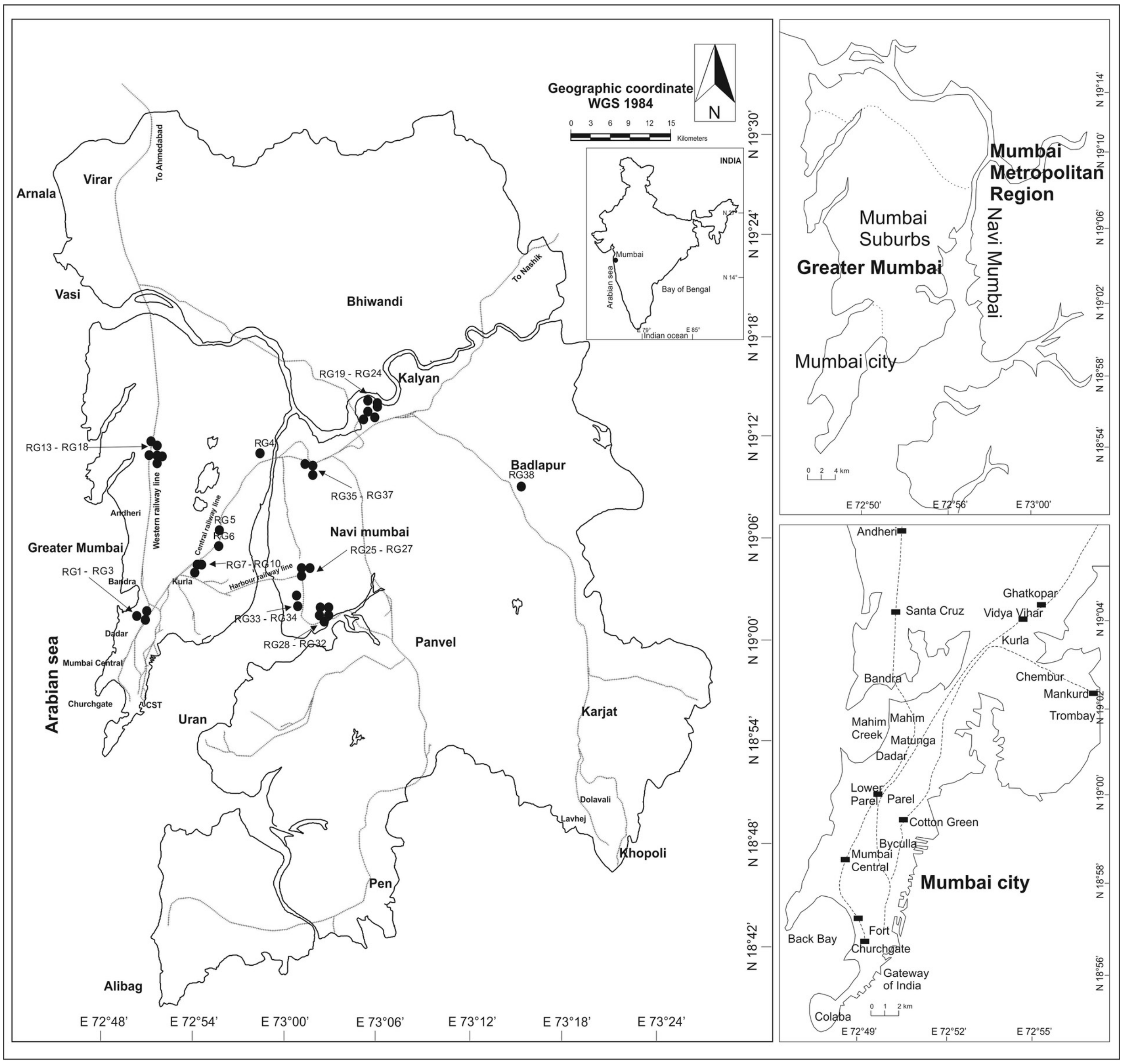

Fig. 2: *Map of Mumbai Metropolitan Region (India) showing the location (black dots) of the 38 selected railway gardens (RG1 – RG38) used in the baseline survey.*

trogen (N), total carbon (C), organic carbon (C_{org}), carbonates, soil fractions, cation exchange capacity (CEC), as well as heavy metals and trace elements including Pb, Cd, As, Cu, Zn, chromium (Cr), nickel (Ni), strontium (Sr), lithium (Li), barium (Ba), cobalt (Co), and boron (B). Soil pH was measured at a ratio of 1:2.5 in an aqueous suspension of soil using a portable pH meter (ORION 4 STAR, Thermo Scientific, Asheville, NC, USA). MF and WC were determined by the oven dry method (550°C for 12 h). SOM was determined by Loss On Ignition after igniting the dry soil for 4 h at 550°C. EC was measured at a ratio of 1:10 aqueous suspension using a portable EC meter (ORION 4 STAR, Thermo Scientific, Asheville, NC, USA).

Total C and total N were measured with a CHNS analyser (FlashEA 1112, Thermo Finnigan, Milano, Italy) and C_{org} were determined using the dichromate oxidation method. Particle size analysis was conducted by the pipette method (Gee & Or, 2002) after dispersion with chemical (0.4 N $NaPO_3$) and physical methods (sieving and sedimentation). Exchangeable cations (Na, K, Ca, and Mg) and CEC were determined by saturation with 1 M CH_3COONH_4 (pH 7.0), washing with 0.05 M CH_3COONH_4 and replacement by 1 M KCl. The degree of base saturation (amount of absorbed cations on exchangeable site of soil) was determined by dividing the sum of exchangeable cations by CEC. Plant available P was measured according to the acid-fluoride procedure of Bray & Kurtz (1945).

To estimate total heavy metal concentrations, 0.2 g soil samples were weighed and transferred to Teflon crucibles. Hydrochloric acid (HCl; 37 %) and nitric acid (HNO_3; 65 %) were mixed at a ratio 3:1 (Aqua regia) and 8 ml of this solution were added to each sample in a Teflon crucible. Then 1 ml perchloric acid (HClO4; 73 %) and 1 ml hydrofluoric acid (HF; 40 %) were added. The Teflon crucibles were placed in a microwave digester (Milestone Inc, Shelton, USA) for 40 minutes at 220°C / 1000 W). After complete digestion, samples were filtered through a Whatman filter paper No 42 (GE Healthcare UK Ltd, Buckinghamshire, UK), the filtrate poured into 25 ml PE volumetric flasks which were then filled up to 25 ml with demineralised water (SG Water, Nashua, NH, USA), and analysed using ICP-AES (Spectro Arcos FHx12a, Spectro Analytical Instruments Inc.,Tokyo, Japan) with a known concentration of multi-element standards ranging from 10 to 1000 ppm (Merck, Rahway, NJ, USA). The readily available heavy metals were determined by semi-sequential extraction using distilled water and 1M NH_4NO_3. Two gram finely powered soil samples were mixed with 50 ml of distilled water and kept in a shaker for 1 h, centrifuged at 4000 rpm, and filtered through a Whatman filter paper No 42. The pellet was resuspended with 50 ml 1M NH_4NO_3, shaken for 2 h, centrifuged and filtered.

2.5 *Produce samples*

Plant samples were freshly collected and transferred to HDPE (High Density Poly Ethylene) bags. These samples were later washed with demineralised water (SG Water, Nashua, NH, USA) and oven-dried to weight constancy at 60°C for 48 h. The dried samples were cut into small pieces, finely powdered, and kept airtight in PE bottles. Later 0.5 g powdered samples were weighed and transferred to Teflon crucibles. These were mixed with 7 ml HNO_3 (65 %), 1 ml H_2O_2 (30 %), and microwave digested for 10 minutes at 220°C / 1000 W). After digestion the samples were filtered through a Whatmann filter paper No 42 and made up to 25 ml, stored in PE volumetric flasks, and analysed using ICP-AES with multi-element standards as above.

2.6 *Statistical analysis*

The survey results were analysed by descriptive statistics using SPSS 12.0 (SPSS Inc., Chicago, IL, USA) and graphs were generated using Sigma plot 7 (Systat Software Inc., Chicago, IL, USA).

3 Results

3.1 *Household classification, structure and level of education*

When asked to self-assess their wealth, 35 respondents described themselves as poor, the other three respondents as medium. Assets such as a car, motorbike, landline, TV, flat, tractor, and/or electricity were absent in all 38 households. However, all respondents owned a mobile phone and a motor pump for irrigation of vegetables (Figure 3).

All households were headed by a married man with an average age of 45 years ranging from 22 to 80 years. The number of family members was heterogeneous varying from one to ten. On average, a family comprised one child (younger than 15 years), three adults between 15 and 55 years and one adult older than 55 years. The average number of household members was five.

In the current study 42 % of the households did not have a chance to attend any school; 8 % and 50 % of them had primary and secondary education. The year of education ranged from zero to twelve years with an average education level of 4.4 years (SD ± 4.3).

3.2 *Migration pattern and UPA production*

Approximately 80 % of the respondents were migrants coming from outside Maharashtra state. The number of years of experience in UPA varied from one to 61 years with an average of 14 years. All interviewed households completely depended on agricultural production and its allied activities to secure their livelihoods. Approximately 97 % of the respondents cultivated vegetables on leased land while the rest were able to grow produce on their own land. Although the majority of land near to tracks belongs to the railways, private ownership was also observed especially in sub-urban areas. The size of the railway gardens ranged from 0.12 to 0.93 with an average of 0.48 ha.

3.3 *Pesticide and fertilizer usage*

The majority of the respondents (97 %) declared to use pesticides in their railway gardens of which the most common were Rogor (Dimethoate 97 %), Cybil (Cypermethrin), Endotaf (Endosulphane 35 %), and Nuvacrone (Monocrotophos 40 %). Also mineral fertilizers were used intensively, including urea (100 %), Sufala (84 %, 15:15:15 NPK) and diammonium-phosphate (DAP, 5 %). In contrast, no compost and cotton cake was applied by any respondent.

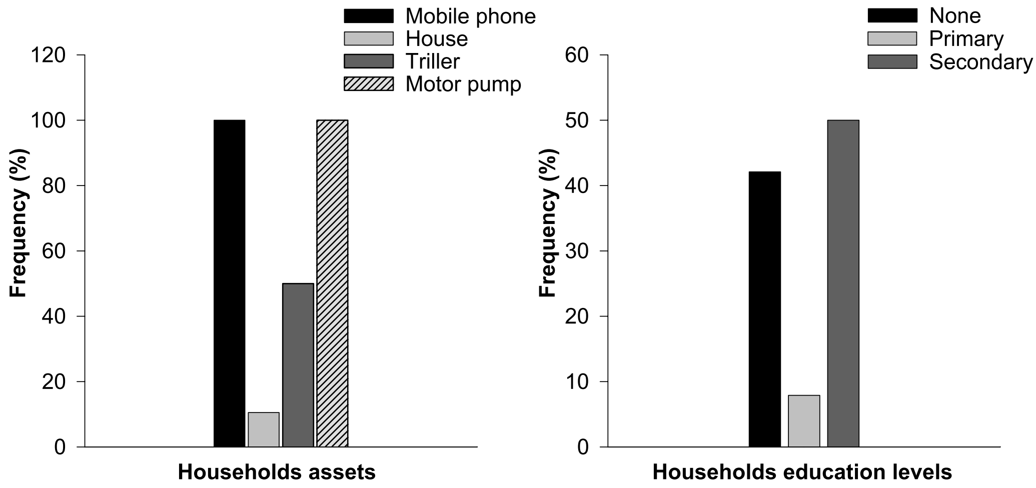

Fig. 3: *Major assets of the 38 households (left) and their education levels (right) among railway garden production systems in the Mumbai Metropolitan Region, India.*

3.4 Labour patterns

Daily wages for workers ranged from 1.8 to 5.6 US$. All hired labourers were migrants from outside Maharashtra who worked for more than six months and were supported with food, accommodation and tobacco. The major activities of the labourers were clearing the land, ploughing, sowing, weeding, irrigation, application of fertilizers and insecticides, harvesting, and transport to the market.

3.5 Investments in UPA production

Major UPA investments were for seeds, fertilizers, pesticides and irrigation (Figure 4). Investments in fertilizer (100 %), seeds (100 %), pesticide (63 %), and irrigation facility (100 %) were only considered if the annual amount spent exceeded 71 US$ (3,000 INR).

3.6 Marketing channels

Marketing channels in MMR are largely well organized and comprise a network of wholesalers, retailers, commission agents, and street vendors (Figure 5). Households sell their products on farm (53 %) or through commission agents (3 %), wholesalers (79 %), retailers (58 %), and direct marketing (24 %). None of the households sold their products through farmers' markets. The producers' focus green leafy vegetables underlines the market demand for these as they are offered fresh without major transportation costs.

3.7 Water usage and quality

All farmers in the railway garden used sewage or wastewater. The major source for sewage water constitutes open sever channels that receive year-round wastewater supply from nearby industries and residential areas including slums. Some of the poor producers admitted that they did not have access to clean water and used motor pumps to irrigate their fields with wastewater of doubtful quality (Figure 6, Table 2). The lowest level of coliforms was 1,100 MPN (Most Probable Number) and the levels were >1,100 MPN at other six sites. Thermotolerent coliforms were present at an average value of 315 MPN (SD, ± 364; Min, 4; Max, 1,100). *Escherichia coli* showed an average value of 284 MPN (SD, ± 361; Min, 0; max, 1,100). Neither *Vibrio* sp. nor *Salmonella* sp. was found in any irrigation water sample.

Table 2: *Heavy metal concentrations in the irrigation water collected from eight railway garden production systems in the Mumbai Metropolitan Region and recommended threshold levels.*

Heavy metal *	*Mean*	*SD*	*Min*	*Max*	*Thresholds*	
Lead (Pb)	0.04	0.01	0.02	0.06	0.2 †a	0.05 ‡b
Cadmium (Cd)	0.74	1.52	0.02	3.47	0.05 †a	0.003 ‡b
Mercury (Hg)	0.002	0.002	0.001	0.005	0.002 †b	0.006 ‡b

* All values in mg l^{-1}; [a] Agricultural Standards; [b] Domestic Standards; † Department of Water Affairs and Forestry (1996), South African Water Quality Guidelines; ‡ WHO (2010)

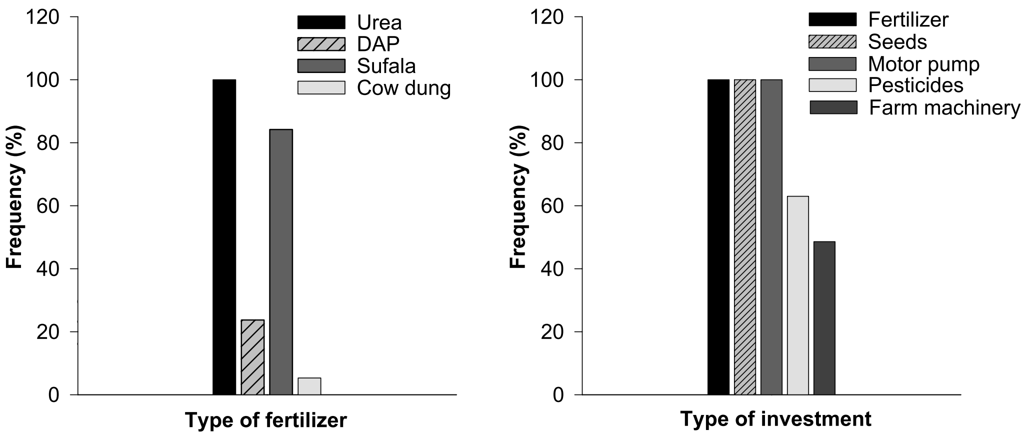

Fig. 4: *Fertilizer usage of the households (left) and major agricultural investments (right) of railway garden production systems in the Mumbai Metropolitan Region, India.*

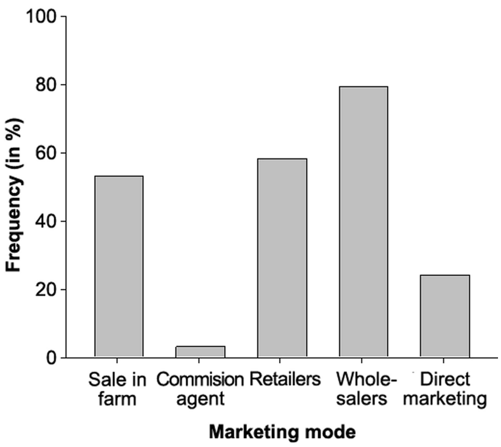

Fig. 5: *Marketing channels among railway garden production systems in the Mumbai Metropolitan Region.*

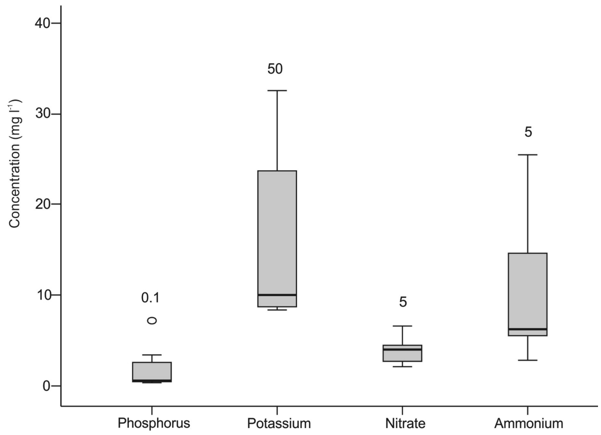

Fig. 6: *Box plot showing the chemical characteristics of the irrigation water in eight railway garden production systems across the Mumbai Metropolitan Region (India) and recommended threshold levels (FAO, 2010) displayed above the whisker.*

3.8 Soil properties

Soil pH of different UPA gardens varied from 3.9 to 6.1 and the EC varied from 0.08 to 0.4 mS m^{-1} (Table 3). Carbonate concentrations varied from 0.20 % to 0.31 %, Na from 0.4 to 1.34 cmol kg^{-1}, and K from 0.2 to 0.6 cmol kg^{-1}. Total C was highest at Thakurli station (19.8 %) where C_{org} was 3.06 %, CEC 14.3 cmol kg^{-1} and base saturation 83 % (Table 3).

Soil concentrations of Cu, Cr, Ni, Sr, Co, and B exceeded the recommended safety thresholds (Table 4–5). Release of H_2O- extractable Cu, Zn, Co, Ni, and Sr were low compared to the respective values with NH_4NO_3-extraction (Table 6).

3.9 Produce quality

Concentrations of total Pb and Cd exceeded the safety thresholds (Table 7) in many vegetables, especially in spinach (3.8 and 1.8 mg kg^{-1}), green amaranth (3.3 and 0.2 mg kg^{-1}), white radish leaves (6.8 and 0.5 mg kg^{-1}), and white radish root (5.7 and 0.2 mg kg^{-1}). In all samples analysed Hg and Ni were below detection limit. High concentrations of Sr (156 mg kg^{-1}) were reported in white radish leaves from Thakurli and of B (37.8 mg kg^{-1}) in spinach from Kalwa.

Table 3: *Statistical Summary of surface soil properties (0–20 cm) of UPA railway gardens (n=4) across the Mumbai Metropolitan Region, India.*

Variable *	*Unit*	*Min*	*Max*	*Mean*	*SD* †
pH (H_2O)		3.87	6.14	5.23	0.97
MF	%	1.03	1.11	1.05	0.03
WC	%	2.87	9.53	5.56	2.81
SOM	%	0.08	0.34	0.15	0.12
Total C	%	0.45	19.84	5.95	9.27
C_{org}	%	0.26	3.06	1.40	1.18
Total N	%	0.04	0.32	0.16	0.12
Sand	%	29.50	73.12	53.54	18.03
Slit	%	19.70	34.74	29.09	6.99
Clay	%	3.88	29.52	17.31	11.27
CEC	cmol kg^{-1}	9.43	14.29	10.82	2.31
Na	cmol kg^{-1}	0.36	1.34	0.70	0.44
K	cmol kg^{-1}	0.20	0.60	0.30	0.20
Ca	cmol kg^{-1}	4.50	7.00	5.70	1.04
Mg	cmol kg^{-1}	2.90	4.00	3.40	0.58
BS	%	83.26	99.11	93.94	7.44
EC	mS m^{-1}	0.08	0.40	0.28	0.13
Acidity		0.09	2.39	0.77	1.09
Carbonates	%	0.20	0.31	0.26	0.05
P	mg kg^{-1}	8.03	556	157	266

* MF, Moisture Factor; WC, Water Content; SOM, Soil Organic Matter; C_{org}, organic carbon; CEC, Cation Exchange Capacity; Na, K, Ca, Mg, exchangeable cations; BS, Base Saturation; EC, Electrical Conductivity; P, plant available phosphorus (Bray P).
† SD, Standard Deviation.

Table 4: *Total cadmium (Cd), lead (Pb), copper (Cu), zinc (Zn), chromium (Cr) and nickel (Ni) concentrations (mg kg^{-1}) in the surface soil (0–20 cm) of UPA railway gardens (n=4) across the Mumbai Metropolitan Region, India.*

Data	*Cd*	*Pb*	*Cu*	*Zn*	*Cr*	*Ni*
Mean	0.5	4.2	144	133	437	103
SD	0.5	1.8	76	18	290	68
Max	1.1	6.9	231	15	791	143
Min	0.1	3.3	60	111	114	1.1
Thresholds						
India *	3–6	250-500	135-270	300	na	75–150
EU †	3	300	140	600	150	20–100
UK †	3	300	80–200	300	400	50–110
USA †	20	150	170	1400	na	210

* Awasthi (2000) and † Canadian Council Ministers of the Environment (CCME, 2001)

Table 5: *Total arsenic (As), strontium (Sr), lithium (Li), barium (Ba), cobalt (Co), and boron (B) concentrations (mg kg^{-1}) in the surface soil (0–20 cm) of UPA railway gardens (n=4) across the Mumbai Metropolitan Region, India.*

Descriptive	*As*	*Sr*	*Li*	*Ba*	*Co*	*B*
Mean	7	166	12	144	39	—
SD	2	33	11	66	13	–
Max	11	209	20	217	55	35
Min	5	127	4	60	24	<0.002
Maximum Allowable Concentration (MAC) *	2–50	120	470	300	20–50	35

* Kabata-Pendias & Pendias (2000)

Table 6: *Soil heavy metal concentrations (mg kg^{-1}) extractable with H_2O and 1M NH_4NO_3 in four UPA railway gardens [nickel (Ni), iron (Fe), copper (Cu), zinc (Zn), cobalt (Co), and strontium (Sr)] across Mumbai Metropolitan Region, India.*

Descriptive	H_2O-*extractable*					NH_4NO_3-*extractable*				
	Cu	*Zn*	*Co*	*Sr*	*Ni*	*Cu*	*Zn*	*Co*	*Sr*	*Ni*
Mean	0.22	1.7	0.03	0.05	0.11	0.47	5.39	0.92	14.62	1.70
SD	0.15	1.3	0.03	0.10	0.07	0.93	7.68	0.62	4.82	0.51
Max	0.30	3.0	0.07	0.20	0.17	1.87	16.3	1.84	26.06	2.06
Min	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.50	2.76	0.94

Table 7: *Concentrations of total copper (Cu), zinc (Zn), chromium (Cr), lead (Pb) and cadmium (Cd) in green amaranth, spinach, and white radish (mg kg^{-1} dry weight) from UPA railway gardens (n=3) across the Mumbai Metropolitan Region, India.*

Data	*Cu*	*Zn*	*Cr*	*Pb*	*Cd*
Mean	7	46	5	5	0.6
SD	4	37	4	2	0.7
Max	13	96	11	7	1.8
Min	3	9	1	3	0.2
Safety Thresholds					
WHO *	40	50	na	0.3	0.2
India †	30	50	20	2.5	1.5

* FAO/WHO (2001), Joint Codex Alimentarius Commission.
† Indian limit, Awasthi (2000)

4 Discussion

The introduction of the “Grow more food” scheme by the Indian Railway Company has multiple functions and goals. In issuing land-use titles priority is given to the weaker sections of the railway employees to allow them to generate additional income for their families. Further goals are the beautification of the tracks, their protection from intrusion of squatters, and additional income generation from the land rent. Though advertised as being part of the Corporate Social Responsibility (CSR) of Indian Railway, the majority of the railway farmers complained about high land rents and lack of basic amenities provided. The tenant farmers may get over-loaded with financial burdens as the railway employees sub-rent the land to other persons or increase the yearly rent.

The results of the self-assessment of gardeners’ income and assets suggests a large gap between two classes of railway gardeners (poor and medium income). The widespread ownership of mobile phones indicates the development in telecommunication and affordability (Dossani, 2002) in megacities such as Mumbai. The lack of formal education in the majority of household heads indicates major poverty hurdles during their childhood. According to Sabir *et al.* (2006) higher household age is one of the major determinants of their poverty.

The majority of immigrants to Mumbai finds jobs in informal sectors such as construction and lives in slums lacking basic amenities (Jen, 2007). The unbalanced urbanization and industrialization process in Asia has resulted in widespread migration of people from rural areas to urban centres where most are reluctant to take up agricultural employment which is comparatively less remunerative (Charsombut, 1981; Shaw, 2004). The opportunities in other sectors of a largely booming economy also stops people, especially the youth, from taking up jobs in the agricultural sector (Byerlee, 1974; Sharma & Bhaduri, 2009). About 80 % of the railway gardeners were immigrants from outside Maharashtra State, predominantly from Uttar Pradesh (UP) and Madhya Pradesh (MP).

All the railway gardeners totally depended on agriculture as their source of income, whereas about 94 % of the railway gardeners cultivated on rented land, while the rest owned the land. The average garden size of 0.48 ha was often split-up into several plots.

The farmers’ intensive use of insecticides and fertilizers reflects gardeners’ strategy to maximize outputs and to shorten growing periods by providing optimal nutrient availability. The preference for urea reflects its easy availability and comparatively low cost. Similarly, investments in irrigation facilities by diesel-operated pumps allowed to boosts the vegetable growth after the Monsoon season. The effective modes of produce delivery to local markets reduce transportation and storage cost, which is of benefit for producers and consumers alike. In addition stringent marketing networks also jobs and income for street vendors.

UPA activities can considerably reduce domestic waste and make life in the cities more sustainable and clean. Street vending of agricultural products in MMR is very common and requires little capital investment and space (Bhowmik, 2000; Saha, 2009; Bhowmik, 2010; Patil, 2010). UPA activities in MMR can also help to strengthen the employment function of the informal sector.

The dependency of railway gardening of wastewater is largely due to the lack of availability of fresh water sources and the year round availability of wastewater. The inadequate drainages and sewage system of the Indian Railways, especially in train stations and railway amenity centres, may be the reason for the direct release of the waste water (Indian Railways, 2007). The high nutrient concentrations in these irrigation water sources will certainly foster the growth of vegetables, but its usage in combination with intensive application of mineral fertilizers will likely lead to a surplus of available nutrients and possibly ground water pollution.

The different national and international standards as well as threshold limits of heavy metals in irrigation water set by various organisations reflect the inconsistency of such regulations. The presence of heavy metals in the irrigation water will over time lead to their accumulation in the soil and subsequently edible plant tissues and may thus affect consumer health (Rattan *et al.*, 2005; Sharma *et al.*, 2007; Singh *et al.*, 2010; Abdu *et al.*, 2011). These heavy metals may come from factories near the sewage supply channel and reflect lacking enforcement of existing norms and regulations. However the atmospheric contribution and deposition of heavy metals should also be considered (Tripathi *et al.*, 2004; Srivastava *et al.*, 2005). On the other hand, the presence of *Escherichia coli* and coliform bacteria in the water likely reflects the open defecation and release of human and animal excreta in the sewage supply channel (WHO, 1989; Sule, 2010). These pathogenic microorganisms can stick to green leafy vegetables and may cause diarrhoea if the latter are consumed fresh (Safi & Buerkert, 2011). Fortunately, this is rather uncommon in India, where most of the culinary traditions prescribe cooking of vegetables rather than their raw consumption. The absence of *Vibrio* sp. and *Salmonella* sp. reduces the spread of contagious diseases, but more detailed studies are needed to assess the health impact of wastewater use. The presence of microorganisms in fruits and juice in Mumbai and their consequences were already investigated by Mahale *et al.* (2008).

The high level of total carbon (19.2 %) and C_{org} (3.06 %) seems unusual for agricultural fields and is known usually from peat soils. The high level of carbon may partly reflect the presence of debris from a coal-based power plant used for the generation of electricity for the locomotives of the Great Indian Peninsula Railway (GIPR). This energy generation started in 1932 and ended in 1988 with a tragic explosion of the boiler (Verma, 2011). The soil from this site had a very high cation exchange capacity and acidity. A more detailed study would be necessary to trace the origin of this soil and its different C fractions.

The presence of Pb and Cd in plant material may in the long term create health hazards for the consumers. These metals are often accumulated in leafy vegetables and root crops when compared to fruits and seeds. It is well known that the uptake of these metals depends on soil and crop factors (McLaughlin *et al.*, 1999). Further study is required to determine the possible interactions, uptake efficiency and ground water leaching of heavy metals under local conditions.

To enhance its long-term economic and ecological viability and to stimulate new developments in UPA such as the implementation of certification systems that help to strengthen consumer-producer relationships, UPA could be linked with existing microfinance programmes. These may allow to strengthen value chains of produce from the poor urban gardeners and contribute to accomplishing the Millennium Development Goals (MDGs) of United Nations especially MDG 1 and 7. While the former calls for halving the proportion of people getting less than 1 US$ a day as well as the proportion of the people suffer from hunger, MDG 7 aims at ensuring environmental sustainability (Mougeot, 2005).

5 Conclusions

Rural to urban migration is creating food insecurities in cities by which the urban poor are often the worst hit. Urban and peri-urban agricultural production such as practiced along the railway tracks in the Mumbai Metropolitan Region plays a vital role in strengthening the livelihood strategies of many poor people by offering food and employment opportunities and allows to recycle substantial amount of organic waste. Like many informal sectors UPA production schemes merit further study and political support. Since migration is a severe social problem in the Mumbai Metropolitan Region, UPA activities can help to bring people out of slums. To strengthen produce quality for consumers' regulations and certification schemes should be implemented.

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References

Abdu, N., Abdulkadir, A., Agbenin, J. O. & Buerkert, A. (2011). Vertical distribution of heavy metals in wastewater-irrigated vegetable garden soils of three West African cities. *Nutrient Cycling in Agroecosystems*, 89 (3), 387–397.

Acharya, A. K. (2004). Population growth and changing land-use pattern in Mumbai Metropolitan Region of India. *Caminhos de Geografia*, 11, 168–185.

APHA (2005). *Standard Methods for the Examination of Water and Wastewater, 21st Ed.*. American Public Health Association, Washington, USA.

Awasthi, S. K. (2000). *Prevention of Food Adulteration Act No. 37 of 1954. Central and State Rules as amended for 1999, 3rd Ed.*. Ashoka Law House, New Delhi, India.

Ayres, R. M. & Mara, D. D. (1996). *Analysis of wastewater for use in agriculture – A Laboratory Manual of Parasitological and Bacteriological Techniques*. World Health Organization (WHO), Geneva, Switzerland.

Bhowmik, S. (2000). Hawkers and urban informal sector: A study of street vending in seven cities. URL `http://www.nasvinet.org/userfiles/file/A%20study%20of%20street%20vending%20in%20seven%20cities.pdf` (last accessed 11.10.2012).

Bhowmik, S. (2010). Urban response to street trading: India. URL http://www.inclusivecities.org/pdfs/bhowmik.pdf (last accessed 11.10.2012).

Bray, R. H. & Kurtz, L. T. (1945). Determination of total, organic, and available forms of phosphorus in soils. *Soil Science*, 59 (1), 39–46.

Bryld, E. (2003). Potentials, problems, and policy implications for urban agriculture in developing countries. *Agriculture and human values*, 20 (1), 79–86.

Byerlee, D. (1974). Rural-urban migration in Africa: theory, policy and research implications. *International Migration Review*, 8 (4), 543–566.

CCME (2001). Canadian water quality guidelines for the protection of aquatic life: Summary table. Canadian Council of Ministers of the Environment (CCME), Winnipeg, Canada.

Charsombut, P. (1981). Labour migration from agriculture in Thailand. SEAPRAP Research, Report No. 55, Institute of South East Asian Studies, Pasir Panjang, Singapore.

De Zeeuw, H., van Veenhuizen, R. & Dubbeling, M. (2011). The role of urban agriculture in building resilient cities in developing countries. *Journal of Agricultural Science*, 149 (S1), 153–163.

Department of Water Affairs and Forestry (1996). *South African Water Quality Guidelines (second edition). Volume 1: Domestic Use*. Department of Water Affairs and Forestry, Pretoria, South Africa.

Dossani, R. (2002). Telecommunications reform in India. *India Review*, 1 (2), 61–90.

Drechsel, P., Graefe, S. & Fink, M. (2007). Rural-urban food, nutrient and virtual water flows in selected West African cities. IWMI Research Report 115, Colombo, Sri Lanka.

FAO (2010). *Irrigation water quality guidelines*. Food and Agriculture Organization (FAO), New York, USA.

FAO/WHO (2001). Food additives and contaminants. Joint Codex Alimentarius Commission, Food and Agriculture Organization of the United Nations/ World Health Organization (FAO/WHO), Food Standards Programme, ALINORM 01/ 12A.

Gee, G. W. & Or, D. (2002). Particle-size analysis. In J. H. Dane, & G. C. Topp (Eds.), *Methods of Soil Analysis, Part 4. Physical Methods* (pp. 255–294). Soil Science Society of America Inc., Wisconsin, USA.

Gerster-Bentaya, M. (2013). Nutrition-sensitive urban agriculture. *Food security*, 5 (5), 723–737.

Graefe, S., Schlecht, E. & Buerkert, A. (2008). Opportunities and challenges of urban and peri-urban agriculture in Niamey, Niger. *Outlook on agriculture*, 37 (1), 47–56.

Hill, K., Quinnelly, D. D. & Kazmierowski, K. (2007). Urban agriculture in Naga city. Cultivating sustainable livelihoods. Planning report for Naga city council June.

Indian Railways (2007). Report no. 6 of 2007 (Railways). Mumbai, India.

Indian Railways (2008). Report no. PA 8 of 2008 (Railways). Mumbai, India.

Jain, J., Grafe, F. J. & Mieg, H. A. (2013). Mumbai, the megacity and global city-A view of the spatial dimensions of urban resilience. In H. A. Mieg, & K. Töpfer (Eds.), *Institutional and Social Innovation for Sustainable Urban Development* (pp. 193–213). Routledge, New York, USA.

Jen, G. (2007). *Mumbai: Global cities*. Evans Brothers Limited, London, UK.

Kabata-Pendias, A. & Pendias, H. (2000). *Trace elements in soils and plants*. CRC Press, Boca Raton, Florida, USA.

Krishna, K. A. & Govil, P. K. (2005). Heavy metal distribution and contamination in soils of Thane-Belapur industrial development area, Mumbai, Western India. *Environmental Geology*, 47, 1054–1061.

Mahale, D. P., Khade, R. G. & Vaidya, V. K. (2008). Microbiological analysis of street vended fruit juices from Mumbai city, India. *Internet Journal of Food Safety*, 10, 31–34.

McLaughlin, M. J., Parker, D. R. & Clarke, J. M. (1999). Metals and micronutrients-food safety issues. *Field crops research*, 60 (1), 143–163.

Midmore, D. J. & Jansen, H. G. P. (2003). Supplying vegetables to Asian cities: is there a case of peri-urban production? *Food Policy*, 28, 13–27.

MMRDA (2010). Draft regional plan for Mumbai Metropolitan Region (MMR). MMRDA, Mumbai, India.

Mougeot, L. J. (2005). *Agropolis: The Social, Political and Environmental Dimensions of Urban Agriculture*. London: Earthscan, London, UK.

Obuobie, E., Keraita, B., Danso, G., Amoah, P., Cofie, O. O., Raschid-Sally, L. & Drechsel, P. (2006). Irrigated urban vegetable production in Ghana: Characteristics, benefits and risks. URL http://www.cityfarmer.org/GhanaIrrigateVegis.html (last accessed 05.06.2012).

Patil, S. (2010). Vegetable hawkers on roadsides: Background for regulation and rehabilitation strategy. URL http://www.scribd.com/doc/19558/Hawking-in-Ahmedabad# (last accessed 18.09.2010).

Pearson, L. J., Pearson, L. & Pearson, C. J. (2010). Sustainable urban agriculture: stocktake and opportunities. *International Journal of Agricultural Sustainability*, 8 (1-2), 7–19.

Rattan, R. K., Datta, S. P., Chhonkar, P. K., Suribabu, K. & Singh, A. K. (2005). Long-term impact of irrigation with sewage effluents on heavy metal content in soils, crops and groundwater-a case study. *Agriculture, Ecosystems & Environment*, 109 (3), 310–322.

Sabir, H. M., Hussain, Z. & Saboor, A. (2006). Determinants of small farmers poverty in the central Punjab (Pakistan). *Journal of Agriculture and Social Sciences*, 2 (1), 10–12.

Safi, Z. & Buerkert, A. (2011). Heavy metal and microbial loads in sewage irrigated vegetables of Kabul, Afghanistan. *Journal of Agriculture and Rural Development in the Tropics and Subtropics*, 112 (1), 29–36.

Saha, D. (2009). Decent work for the street vendors in Mumbai, India: A distant vision. *Journal of Workplace Rights*, 14 (2), 229–250.

Sharma, A. & Bhaduri, A. (2009). The “tipping point” in Indian agriculture: Understanding the withdrawal of the Indian rural youth. *Asian Journal of Agriculture and Development*, 6 (1), 83–97.

Sharma, R. K., Agrawal, M. & Marshall, F. (2007). Heavy metal contamination of soil and vegetables in suburban areas of Varanasi, India. *Ecotoxicology and Environmental Safety*, 66 (2), 258–266.

Shaw, A. (2004). *The making of Navi Mumbai*. Orient Longman Private Limited, Hyderabad, India.

Singh, A., Sharma, R. K., Agrawal, M. & Marshall, F. M. (2010). Health risk assessment of heavy metals via dietary intake of foodstuffs from the wastewater irrigated site of a dry tropical area of India. *Food and Chemical Toxicology*, 48 (2), 611–619.

Sinha, A. (2009). Agriculture and Food Security: Crises and Challenges Today. *Social Action*, 59 (2), 1–16.

Srivastava, A., Joseph, A. E., More, A. & Patil, S. (2005). Emissions of VOCs at urban petrol retail distribution centres in India (Delhi and Mumbai). *Environmental Monitoring and Assessment*, 109 (1-3), 227–242.

Sule, S. (2010). Sanitation system for Mumbai. Understanding our civic issues. The Bombay Community Public Trust (BCPT), Mumbai, India.

Tripathi, R. M., Vinod Kumar, A., Manikandan, S. T., Bhalke, S., Mahadevan, T. N. & Puranik, V. D. (2004). Vertical distribution of atmospheric trace metals and their sources at Mumbai, India. *Atmospheric Environment*, 38 (1), 135–146.

UN (2010). World Urbanization Prospects - The 2009 Revision. United Nations (UN), New York, USA.

Verma, K. (2011). On revival path, Thakurli unit to get back power after 23 years. URL http://www.indianexpress.com/news/on-revival-path-thakurli-unit-to-get-back-power-after-23-years/765418 (last accessed 23.11.2012).

WHO (1989). *Health guidelines for the use of wastewater in agriculture and aquaculture. Technical Report Series No. 778*. World Health Organization (WHO), Geneva, Switzerland.

WHO (2010). *Guidelines for drinking water quality*. World Health Organization (WHO), Geneva, Switzerland.