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CARBON ECONOMY AND HEAVY METAL CONTAMINATION IN TWO PERI-URBAN AREAS OF DHAKA CITY IN RELATION TO INDIGENOUS VEGETABLE CULTIVATION PRACTICES

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Abstract

A study was conducted to observe the pattern of carbon economy and the extent of heavy metal (Pb, Cd, Fe, Mn, Zn, Cu and Ni) contamination under vegetable cultivation in the peri- urban areas of Dhaka city. For this research work, soils under different vegetables and rice cultivation as well as under no cultivation practices and the growing plants were collected from two peri-urban areas around Dhaka city- one from Narsingdi area where sustainable conservation practices have been adopted under vegetable cultivation and another from Dhamrai area where crops (vegetables and rice) are cultivated in a traditional way. The fields in Narsingdi area were along the Dhaka- Sylhet highway whereas the fields in Dhamrai area were at an interior area and far away from Dhaka- Aricha highway. The vegetable fields under sustainable agricultural practices sequester more C than rice and uncultivated fields. The contents of heavy metals in soils under different agricultural practices and accumulation of those metals in cultivated plants showed a wide variability. The mean concentrations of heavy metals (Pb, Cd, Fe, Mn, Cu and Ni) in soils were found to be lower in fields along the road side than that in the interior area. On the other hand, the mean concentrations of Pb, Cd, Mn and Cu in plants were higher in road side vegetables than in vegetables of the interior area. Both positive and negative relationships were observed between the carbon and heavy metal contents in soils for individual soils. But most of the correlations were insignificant. The assessment of contamination of arable lands and vegetables cultivated in the peri- urban areas of Dhaka city has been found to be soil type, crop, agricultural practices, type of fertilizers and pesticides and heavy metal species dependent.

Keywords: Peri-urban agriculture, carbon sequestration

Introduction

Peri-urban agriculture is the practice of cultivating, processing and distributing food around a village, town or city. It contributes to local economic and micro-enterprise development, poverty alleviation, food security, the productive reuse of urban organic

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wastes and wastewater; the greening of the city and maintenance of its biodiversity. Peri-urban agriculture is not only associated with the purposeful production of food and fiber commodities, it is also concerned with environmental mitigation. Terrestrial carbon sequestration involves capture of atmospheric carbon through photosynthesis and storage in biota, soil and wetlands. It has been reported that land use, vegetation and soil management have a strong impact on the biotic processes of carbon sequestration (Lal 2004).

Peri-urban lands around Dhaka city – the ever growing capital of Bangladesh, are often used for production of vegetables for better market accessibility and higher prices, which can contribute to the sequestration of carbon resulting from the rapid urbanization of Dhaka city. In Bangladesh, most of the land is cultivated for rice as rice is our staple food. Still now, the area under vegetable cultivation is insignificant. However, the farmers are becoming interested to cultivate vegetables because of its high return. More and more lands around the periphery of the Dhaka city are being brought under vegetable cultivation. This changed scenario has prompted us to go for an assessment of carbon sequestration under vegetable cultivation in comparison to the traditional rice cultivation and uncultivated land as well as the food quality *vis-à-vis* the heavy metal contents. The peri-urban lands are contaminated with heavy metals through vehicular emission (Imamul Huq *et al.* 2000, Imamul Huq and Islam 1999), application of pesticides, herbicides or insecticides, presence of heavy metals in fertilizers as impurities, application of sewage sludge, irrigation water, etc. It has been reported that, Pb, Cd, Cu, Ni and Zn may interfere with the uptake and distribution of essential mineral nutrients in the plants (Trivedi and Erdei 1992). These result in contaminating the vegetables cultivated on those lands with heavy metals that could be of serious health hazards to the consumers. Peri-urban agriculture thus bears this risk.

The present study focuses on the assessment of carbon sequestration in peri-urban agricultural lands (vegetables and rice) and fallow lands. Besides, the trends of accumulation of heavy metals in vegetables and rice lands as well as in plants (vegetables and rice) are also considered.

Materials and Methods

The present experiment was carried out to study the carbon (C) and heavy metal (Pb, Cd, Fe, Mn, Zn, Cu and Ni) contents of soils in several fields of two peri-urban areas around Dhaka city in Bangladesh. Soils under different vegetable and rice cultivation as well as under no cultivation practices were collected from two peri-urban areas- one from Narsingdi area and another from Dhamrai area.

Description of Sampling Sites

Narsingdi area: The soil and plant samples were collected from the agricultural fields of surrounding area of Dhaka-Sylhet highway in Village: Khundapara, Thana: Shibpur, District: Narsingdi where sustainable conservation practices have been adopted under vegetable cultivation. The geo-location of the sampling site is 24 ° 00.07′ N and 90 ° 46.297′ E (Figure 1). The soils are Old Brahmaputra Floodplain belonging to Sonatala series. Four sampling spots were selected from the Narsingdi sampling site. Soil and plant samples were collected from each spot except spot 4. Only soil sample was collected from spot 4 as there were no agricultural practices and for the present purpose, spot 4 is used as control field condition. Spot 3 was selected from rice field to compare the carbon and heavy metal contents in soil and plant between vegetables and rice.

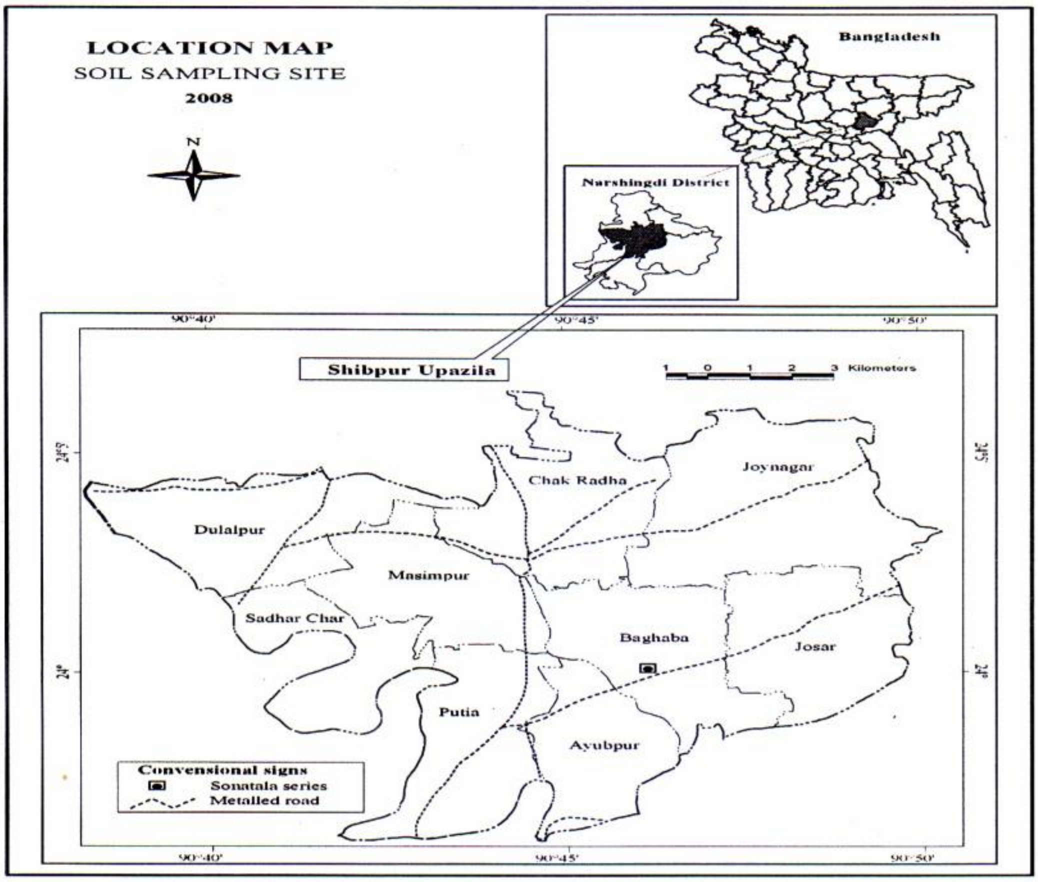

Figure 1. GPS-GIS based location map of the soil sampling sites of Narsingdi.

Dhamrai area: Samples were collected from the agricultural fields of surrounding area of Dhamrai in Village: Bashna, Union: Shanora, Thana: Dhamrai, District: Dhaka. The geo-location of the sampling site is 23 ° 56.7.6′ N and 90 ° 07.720′ E (Figure 2). The soils are Young Brahmaputra Floodplain belonging to Melandaha series. The sampling sites were selected from the interior area of Dhamrai and far away from Dhaka-Aricha highway. Five sampling spots were selected from the Dhamrai sampling site. Soil and plant samples were collected from each spot except spot 5. Only soil sample was collected from spot 5 as there were no agricultural practices and for the present purpose, spot 5 is used as control field condition. Spot 4 was selected from rice field to compare the carbon and heavy metal contents in soil and plant between vegetables and rice.

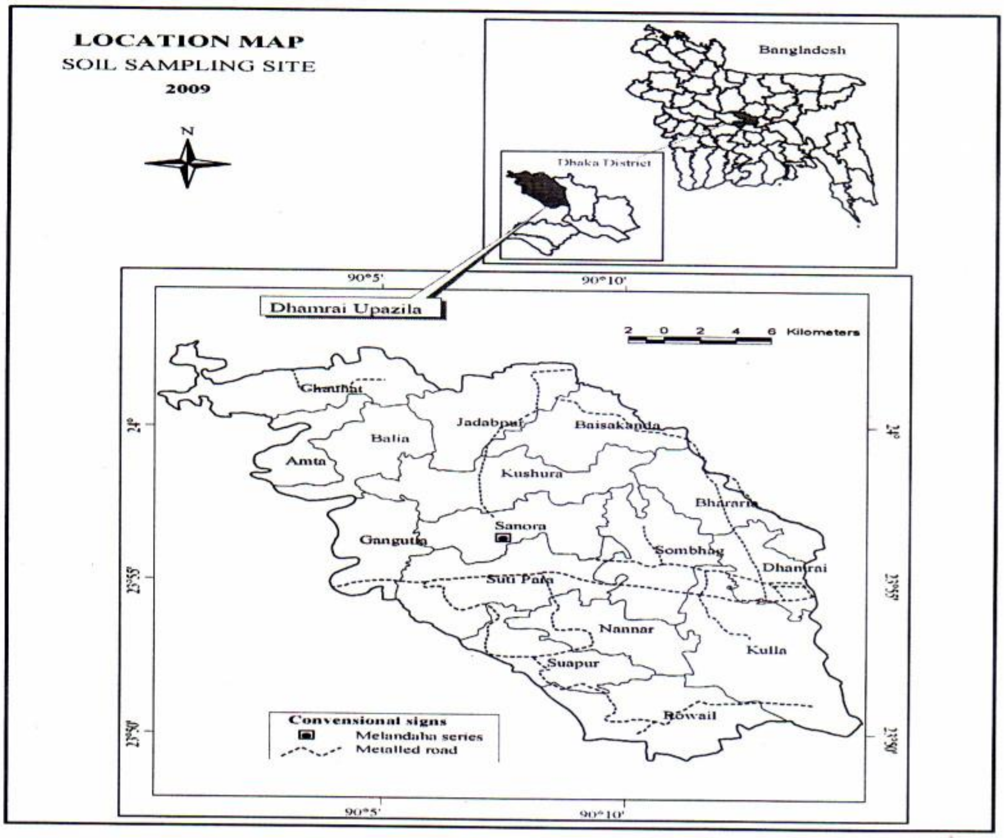

Figure 2. GPS-GIS based location map of the soil sampling sites of Dhamrai.

List of agricultural fields from where soils samples were taken and the respective collected plant samples are shown in Table 1.

Table 1. Sampling sites and collected plant samples

Sampling Site	Spot	Soil Samples	Plant Samples	
			Local Name	Botanical Name
Site 1 Narsingdi Area	1	Bean Field	Bean	*Lablab niger*
	2	Brinjal Field	Brinjal	*Solanum melongena*
	3	Rice Field	Rice	*Oryza sativa*
	4	Control Field	-	-
Site 2 Dhamrai Area	1	Dhundul Field	Dhundul	*Luffa cylindrica*
	2	Brinjal Field	Brinjal	*Solanum melongena*
	3	Patal Field	Patal	*Trichosanthes dioica*
	4	Rice Field	Rice	*Oryza sativa*
	5	Control Field	-	-

Collection and Processing of Soil and Plant Samples

Soils from 0-15 cm depth were collected from two areas. Composite soil sampling was done from each sampling spot with the help of an auger as suggested by the Soil Survey Staff of the USDA (1951). The collected soil samples were dried in air, ground, sieved and preserved for physical, chemical and physico-chemical analysis. The naturally growing as well as cultivated plants in those arable fields were also collected from both areas to evaluate the response to the contaminants by vegetables. Plant samples were also dried, ground and preserved.

Analysis of soil and plants

Various physical, chemical and physico-chemical parameters of the soil samples were analyzed in the laboratory in order to assess their nutritional and heavy metal status of the soils.

The Particle size analysis of the soil samples was done by Hydrometer method (Piper 1950). Soil pH was determined immediately after transportation of the soil samples to the laboratory and was measured electrochemically by using a glass-electrode pH meter at a soil:water ratio of 1: 2.5. Organic carbon of the soil samples was determined by wet oxidation method of Walkley and Black as described in Imamul Huq and Alam (2005). Total nitrogen of the soil samples was determined by steam distillation of the Kjeldahl digest (Jackson 1962). The available phosphorus of the soils was extracted by using the Bray & Kurtz method and the extracts were used to estimate the P colorimetrically by following the blue color method using ascorbic acid by spectrophotometer at 880 nm. The available potassium of the soils was determined by flame analyzer after extracting the soils with 1N ammonium acetate at pH 7.0. The total phosphorus content of the soils was determined colorimetrically using a spectrophotometer at 490 nm by developing yellow color with vanadomolybdate after the extract was collected by digesting the soil with HNO_3-$HClO_4$ (Jackson 1962). Total potassium content of the soils was determined by digesting the soils with aqua-regia (HCl: $HNO_3 \equiv 3{:}1$) by a flame analyzer. Total sulphur content of soils was determined by turbidimetric method by spectrophotometer at 420 nm after HNO_3-$HClO_4$ digestion.

Total lead (Pb), cadmium (Cd), iron (Fe), manganese (Mn), zinc (Zn), copper (Cu) and nickel (Ni) contents of the soils and plant samples were determined by atomic absorption spectrometer (AAS) using the aqua-regia (HCl: $HNO_3 \equiv 3{:}1$) and nitric acid (HNO_3) digest respectively.

All data were analysed by using Microsoft Excel and/or MINITAB (version 13) Packages.

Results and Discussion

The results of physical, chemical and physico-chemical properties of the soils of Narsingdi and Dhamrai areas are presented in Table 2. In the text, the local name of the plants has been used.

Table 2. The physical, chemical and physico-chemical properties of the soils of Narsingdi (site 1) and Dhamrai (site 2).

Site	Spot	Moisture (%)	pH	Sand (%)	Silt (%)	Clay (%)	Textural Class	Available P (mg kg^{-1})	Available K (mg kg^{-1})	Total N (%)	Total P (%)	Total K (%)	Total S (%)
Site 1	1	4.3	4.6	35.6	44.3	20.1	Loam	141.8	192.6	0.4	0.07	0.18	0.23
	2	9.6	5.7	29.6	46.6	23.8	Loam	126.4	380.2	0.36	0.07	0.28	0.22
	3	5.4	5.7	34.9	42.2	22.9	Loam	12.4	58.6	0.25	0.03	0.19	0.24
	4	5.0	6.2	53.5	28.9	17.6	Sandy Loam	16.6	58.9	0.14	0.01	0.12	0.2
Site 2	1	8.7	5.9	38.3	46.2	15.9	Loam	112.2	67.3	0.20	0.06	0.76	0.3
	2	12.0	5.9	36.4	47.6	16.0	Loam	157.4	94.1	0.25	0.07	0.61	0.27
	3	5.3	5.4	42.8	44.8	12.4	Loam	143.4	94.4	0.2	0.09	0.67	0.20
	4	15.3	5.6	37.4	46.1	16.4	Loam	16.00	656	0.17	0.04	0.48	0.26
	5	10.3	5.6	37.5	46. 9	15.7	Loam	12.4	83.9	0.2	0.03	0.62	0.18

Soil Carbon

Vegetable fields sequestered more C than any other fields in both Narsingdi and Dhamrai areas (Table 3). The vegetable fields in Narsingdi, under sustainable agricultural practices, sequestered more C (2.8 % on average) than those in Dhamrai (1.18 % on average), under traditional agricultural practices. The average C contents in rice and in control fields were 2.5 % and 1.17 % in Narsingdi and 0.93 % and 0.96 % in Dhamrai respectively.

Table 3. Contents of C in soils under different cultural practices in Narsingdi and Dhamrai.

Site	Spot	Soil Samples	C Content (%)
Site 1	1	Bean Field	2.64
	2	Brinjal Field	2.91
	3	Rice Field	2.51
	4	Control Field	1.17
Site 2	1	Dhundul Field	1.0
	2	Brinjal Field	1.42
	3	Patal Field	1.13
	4	Rice Field	0.93
	5	Control Field	0.96

It is apparent from the present observations that the carbon content is higher in the soils under vegetable cultivation than any other cultivation practices. The maximum carbon content was found in the vegetable fields of Narsingdi area. The existence of sustainable agricultural practices in Narsingdi might have contributed to this phenomenon. The farmers cultivate vegetables on raised platform. In every 3-4 years period, they cultivate rice to reclaim the nutrient status of soil.

Heavy Metals in Soils

The contents of heavy metals (Pb, Cd, Fe, Mn, Zn, Cu and Ni) found in the soils of Narsingdi and Dhamrai area are presented in Table 4.

Table 4. Contents of heavy metals in soils under different cultural practices in Narsingdi and Dhamrai.

Site	Spot	Type of Field	Pb (mg kg^{-1})	Cd (mg kg^{-1})	Fe (%)	Mn (mg kg^{-1})	Zn (mg kg^{-1})	Cu (mg kg^{-1})	Ni (mg kg^{-1})
Site 1	1	Bean	13	0.23	1.55	323	71.4	24.0	16.7
	2	Brinjal	14.4	0.12	1.70	406	96.7	20.3	18.0
	3	Rice	13.7	0.14	1.87	336	67.7	19.1	19.4
	4	Control	9.2	0.07	1.46	353	44.7	13.1	12.0
Site 2	1	Dhundul	21.5	0.27	1.78	1132	61.0	27.8	23.2
	2	Brinjal	20.6	0.31	2.29	728	80.10	28.4	34.5
	3	Patal	40.3	0.19	1.93	484	57.80	23.2	27.8
	4	Rice	42.2	0.27	2.22	508	77.00	26.4	29.6
	5	Control	39.9	0.25	2.28	564	64	30.6	32.9

In Narsingdi area, the mean concentrations of Pb, Cd, Mn, Zn and Cu along the road side areas were found to be higher in vegetable soils than in rice soils. The mean total contents of Pb, Cd, Mn, Zn and Cu in vegetable and rice soils were 13.7, 0.18, 364.66, 84.06, 22.14 and 13.67, 0.14, 335.99, 67.68, 19.1 mg kg^{-1} respectively. The contents of Fe and Ni were found to be higher in rice fields than in vegetable fields; the mean concentrations of Fe and Ni in vegetable soils were 1.63 % and 17.35 mg kg^{-1} respectively while in rice soils the values were 1.9 % and 19.41 mg kg^{-1} respectively. The concentrations of Pb, Cd, Fe, Mn, Cu and Ni in vegetable soils were found to be lower than the threshold values; only Zn was found in excess of the threshold level. In Narsingdi, the heavy metal contents in vegetable fields were higher than those in control fields.

In Dhamrai, the mean concentrations of Pb, Cd, Fe, Zn, Cu and Ni were found to be higher in rice soils than in vegetable soils. The mean total contents of Pb, Cd, Zn, Cu and Ni in vegetable and rice soils were 27.45, 0.26, 66.39, 26.46, 28.5 and 42.2, 0.27, 77.02, 26.39, 29.64 mg kg^{-1} respectively. The average Fe contents were found to be 2% and 2.22 % for vegetable and rice soils respectively. Only Mn content was found to be higher in vegetable soils than in rice soils; the mean concentrations of Mn in vegetable and rice soils were 781.44 and 508.11 mg kg^{-1} respectively. In Dhamrai, most of the heavy metal contents in vegetable fields were lower than those in control fields. The concentrations of Pb, Cd, Fe, Cu and Ni in vegetable soils were found to be in the contamination levels.

It was expected that, heavy metal contents in Narsingdi soils would be higher than those in Dhamrai soils as the fields were along the highway in the former case whereas the second fields were far away from the highway. It was observed however, that, the heavy metal (Pb, Cd, Fe, Mn, Cu and Ni) contents were higher in the Dhamrai soils than the Narsingdi soils except for Zn. This is an indication that the metals are in more labile form in the latter than in the former case.

In most of the cases, the fields under agricultural practices contained more heavy metals than uncultivated lands in Narsingdi. A reverse observation was made in Dhamrai. Presence of higher amount of heavy metals in soils under agricultural practices in Narsingdi could be related either to the presence of heavy metals in fertilizers as impurities or because of use of pesticides, insecticides or herbicides. Lesser amount of heavy metal in the control field is obvious as these soils do not receive any fertilizer amendments or pesticides. On the other hand, presence of lesser amount of heavy metals in the agricultural fields of Dhamrai could be related to the agricultural practices and/or the nature of the soil. It needs to be mentioned here that, the soils of Narsingdi belong to Sonatala series whereas those of Dhamrai belong to the Melandaha series.

Compared to the rice fields, the heavy metal contents in vegetable fields showed inconsistencies in both Narsingdi and Dhamrai areas. For example, brinjal soil contained more Fe than rice fields in Narsingdi whereas in Dhamrai the reverse was observed. It might be due to the differences in soil types, nature of plants, extent and type of fertilizers and pesticides applied to the fields, etc. between the two areas.

Heavy Metals in Plants

The contents of heavy metals (Pb, Cd, Fe, Mn, Zn, Cu and Ni) found in the vegetables and rice of Narsingdi and Dhamrai area are presented in Table 5.

Table 5. Contents of heavy metals in plants under different cultural practices in Narsingdi and Dhamrai.

Site	Type of Plants	Pb (mg kg^{-1})	Cd (mg kg^{-1})	Fe (mg kg^{-1})	Mn (mg kg^{-1})	Zn (mg kg^{-1})	Cu (mg kg^{-1})	Ni (mg kg^{-1})
Site 1	Bean	10.67	0	135.69	31.33	45.92	28.31	10.6
	Brinjal	10.5	0.23	255.47	19.33	17.32	30.07	5.91
	Rice Grain	8.33	0.43	131.8	180.3	12.32	13.61	4.5
	Rice Straw	12.67	0.23	293.38	924.8	24.20	33.47	6.36
Site 2	Dhundul	0	0	151	14.28	50.86	26.67	8.14
	Brinjal	0	0	212	10.78	25.45	17.55	6.02
	Patal	0	0	344.75	14.53	41.75	17.72	9.96
	Rice Straw	0	0	665.75	372.2	46.15	16.13	6.44

In Narsingdi, the Pb, Zn, Cu and Ni contents were higher in the edible parts of vegetables than in rice (straw and grain); the mean concentrations of Pb, Zn, Cu and Ni were found to be 10.60, 31.62, 29.19, 8.26 and 10.5, 18.26, 23.54, 5.43 mg kg^{-1} respectively in vegetables and in rice (straw and grain) respectively. On the other hand, the mean concentrations of Fe, Cd and Mn were much higher in rice (212.59, 0.33 and 552.55 mg kg^{-1} for Fe, Cd and Mn respectively) than in vegetables (195.68, 0.12 and 25.33 mg kg^{-1} for Fe, Cd and Mn respectively). The mean contents of Pb, Fe, Mn, Zn, Cu and Ni in vegetables exceeded the threshold level.

In Dhamrai, the contents of Pb and Cd were found to be below detectable limit for both vegetables and rice. The mean contents of Fe, Mn and Zn were much higher in rice straw (665.75, 372.2 and 46.15 mg kg^{-1} for Fe, Mn and Zn respectively) than in vegetables (235.92, 13.2 and 39.35 mg kg^{-1} for Fe, Mn and Zn respectively). Only the contents of Cu and Ni were higher in vegetables than in rice straw, the mean contents of Cu and Ni were 20.65, 8.04 and 16.13, 6.44 mg kg^{-1} respectively for vegetable and rice. The mean contents of Fe, Zn and Ni in vegetable exceeded the threshold level.

An assumption was made that the metals are in more labile form in Narsingdi soils than in Dhamrai soils when the heavy metal contents were found higher in Dhamrai soils than in Narsingdi soils. The assumption was proved correct when high accumulation of

Pb, Cd, Mn and Cu was found in plants from Narsingdi. In Dhamrai Pb and Cd contents in crops were found to be below detectable limit. This could be related to the fact that heavy metal mobility in soil and its subsequent accumulation in plants are governed by soil characteristics like pH and organic matter content, heavy metal species as well as the characteristics of the root exudates. The characteristics of the root exudates are dependent on the type of plants (Alloway 1990, Chowdhury *et al.* 2009).

The higher accumulation of heavy metals in crops cultivated along the highway of the peri-urban areas could be of concern for heavy metal toxicities to both human and animals through their entry into food chain.

Compared to the vegetables, rice accumulated higher amount of Fe and Mn in both Narsingdi and Dhamrai areas. The Mn content was always higher in vegetables than in rice in both the areas. The accumulation of Pb, Cd, Zn and Cu in vegetables and rice showed inconsistencies. The difference in the level of heavy metal contamination among different vegetables and rice in two different areas was possibly due to their morpho-physiological differences in terms of heavy metal uptake, exclusion, accumulation, foliage deposition and retention efficiency.

Correlation between carbon and heavy metal contents for individual soil

Both positive and negative relationships were found between the carbon and heavy metal contents in soils for individual soils(Tables 6 and 7). But most of the correlations were insignificant. Only Cu contents in soils under "Patal" cultivation showed highly

Table 6. Correlation coefficient values between carbon and heavy metal contents in soils of Narsingdi area.

Soil C	Soil Pb	Soil Cd	Soil Fe	Soil Mn	Soil Zn	Soil Cu	Soil Ni
Control	0.596	-0.189	-0.767	0.381	0.865	-0.500	-0.500
Bean	-0.327	0.832	-0.960	-0.064	-0.292	-0.831	0.950
Brinjal	-0.982	-0.500	0.624	-0.832	0.552	0.257	0.867
Rice	-0.945	0.655	-0.928	-0.143	0.185	-0.687	-0.189

Table 7. Correlation coefficient values between carbon and heavy metal contents in soils of Dhamrai area.

Soil C	Soil Pb	Soil Cd	Soil Fe	Soil Mn	Soil Zn	Soil Cu	Soil Ni
Control	-0.999 [b]	-0.240	-0.133	0.561	-0.465	0.999 [b]	0.993
Dhundul	-0.359	0.693	-0.683	0.896	-0.456	-0.717	0.819
Brinjal	0.321	-0.891	-0.602	0.964	-0.951	-0.976	-0.971
Patal	0.092	-0.786	-0.312	0.791	0.245	-1 [a]	-0.958
Rice	0.224	0.500	0.362	0.526	0.732	-0.980	-0.856

[a] denotes significance at $p = 0.001$ [b] denotes significance at $p = 0.02$

significant ($p = 0.001$) negative correlation with its C content in Dhamrai area. The assessment of contamination of arable lands and vegetables cultivated in the peri- urban areas of Dhaka city has been found to be soil type, crops, agricultural practices, type of fertilizers and pesticides and heavy metal species dependent.

Conclusion

Peri-urban farmers and consumers should know the importance of peri-urban farming and their environmental impacts as well. Understanding the hazards for producers, consumers and on the urban ecosystem is essential for determining strategies that multiply benefits and mitigate risks. With effective urban planning, peri-urban agriculture can grow and blossom into its full potential keeping their negative impacts under tolerance level. With this point of view, sustainable peri-urban agriculture is required. The sustainability of peri-urban agriculture will depend on proper developmental policy from the government. Finally, there is a need for local authorities, especially cities, to take an important role in promoting peri-urban agriculture since it has a vital implication in the vegetable basket of the urban population.

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