RESEARCH REPORT

115

Rural-Urban Food, Nutrient and Virtual Water Flows in Selected West African Cities

Pay Drechsel, Sophie Graefe and Michael Fink

International Water Management Institute

COMPREHENSIVE Assessment of water management in agriculture

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P O Box 2075, Colombo, Sri Lanka

IWMI receives its principal funding from 58 governments, private foundations, and international and regional organizations known as the Consultative Group on International Agricultural Research (CGIAR). Support is also given by the Governments of Ghana, Pakistan, South Africa, Sri Lanka and Thailand.

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Acknowledgements: The authors acknowledge the input from a number of colleagues, especially Philip Amoah, Olufunke O. Cofie, Lucy Gyiele, Charlotte de Fraiture and Eric Craswell. Different departments and faculties at the Kwame Nkrumah University of Science and Technology (KNUST) in Kumasi, the University of Ghana in Accra, and the University for Development Studies (UDS) in Tamale, were involved in parts of the studies. We are grateful to the students who helped to compile the data presented in this report, especially Christoph Leitzinger, Martin Ngenge, Peter Hoefer, Steve Ameyibor, Johanna Gellermann, Alexandra Tessier, Marco Erni, Anselm Vodounhessi, George Danso, Mirth Fafa Avotri and Manuel Henseler. Amah Klutsé from the Centre Régional pour l'Eau Potable et l'Assainissement à faible coût (CREPA) and Bado Nebilma from the Direction Régionale de l'Agriculture (DRA) in Burkina Faso supervised parts of the studies in Ouagadougou. We are indebted to SANDEC/EAWAG and the Swiss Federal Institute of Technology in Switzerland for introducing us to the Material Flow Analysis in the Kumasi pilot study. The Comprehensive Assessment of Water Management in Agriculture supported our data collection in Burkina Faso, while the International Development Research Centre (IDRC) in Canada supported parts of the fieldwork in Ghana in the frame of project 100376: Improving the rural-urban nutrient cycle through peri-urban agriculture.

Drechsel, P.; Graefe, S.; Fink, M. 2007. *Rural-urban food, nutrient and virtual water flows in selected West African cities*. Colombo, Sri Lanka: International Water Management Institute. 35p (IWMI Research Report 115)

/ food consumption / nutrients / water quality / food production / water demand / food production / urban agriculture / West Africa /

ISSN 1026-0862
ISBN 978-92-9090-669-8

Cover Photograph: Market woman in Accra, Ghana (photo credit: IWMI)

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Contents

Summary

Impacts of increasing population pressure on food demand and land resources have sparked interest in nutrient balances and flows at a range of scales. This study quantifies rural-urban food flows in Ghana and Burkina Faso and analyses the dependency of four cities – Accra, Kumasi, Tamale and Ouagadougou - on food supplied from rural, peri-urban and urban areas as well as from imports. While the majority of calorie-rich food is derived from rural areas, urban and peri-urban farms provide significant shares of certain, usually more perishable, commodities. Many of these food items are not part of traditional diets, but are a key component of the urban fast-food and street food sectors. Food imports provide, in particular, commodities popular in cities, like rice and poultry, and dominate the supply of processed food.

The overall urban dependency on rural agriculture is reflected in the extensive cropping areas needed to provide food for the cities. With every harvest, the soils in the production areas export some of their fertility, which creates a negative 'urban nutrient footprint'. However, cities are not only nutrient sinks, they also have a strong 'urban water footprint', considering that besides the domestic water demand there is also the water required to produce the food that is consumed.

Both, the nutrient and water footprints are closely interlinked. Currently, 95 percent of the domestic water used in Kumasi and 80 percent of the nutrients consumed go to waste without controlled treatment or resource recovery. The water required to dilute the polluted urban return flow is significantly increasing the 'urban water footprint' and its hidden environmental costs, which add to the monetary value of the lost nutrients. The role of urban and peri-urban agriculture and options to reduce the environmental burden by closing the rural-urban water and nutrient cycles are discussed.

Rural-Urban Food, Nutrient and Virtual Water Flows in Selected West African Cities

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"The world and its cities are thirsty for water, but too often it is forgotten that they are far more hungry for water"
(Varis 2006)

Introduction

Background

Food production is the biggest consumer of both water and nutrients in the world. Human-induced changes to the cycling of water and nutrients in terrestrial ecosystems can significantly affect the sustainability of food production, the state of the natural resource base, and the health of the environment. One of the changes is the process of rapid urbanization, which raises the spatial challenges on how to make sufficient food available for a locally agglomerating population, and how to manage the related waste flows. In sub-Saharan Africa where farm soil is already receiving less inputs than required to compensate for local losses (Henao and Baanante 1999), the problem is exacerbated by the export of nutrients in harvested food to urban areas with little or no return of organic residues into the food production process (Drechsel and Kunze 2001). An exception is urban and peri-urban agriculture, which could absorb parts of the waste to close the nutrient loop. However, most nutrients end up in landfills or polluted urban soils and water bodies, which link the urban nutrient and water cycles. In the case of Bangkok, for example, Faerge et al. (2001a, 2001b) estimated that more than 90 percent of the 26,000 tons (t) of nitrogen that annually enter the city, are lost again, mainly through Bangkok's waterways. Besides the actual urban water consumption, the demand for water is even greater if we consider the, so called 'virtual water' needed to produce the required urban food.

Aims of the Study

Resource flow analysis has been used to estimate the Ecological Footprint of nations, regions and cities (Chambers et al. 2000). While the calculations for global and national footprints have been standardized (WWF 2006), there are a variety of methods used to calculate the footprint of a city or region, including virtual water demands (Friends of the Earth 2001). In our study, we focused only on nutrients and water flows and did not attempt to provide a complete footprint analysis or a full life cycle accounting where everything used along the production chain is taken into account. Rather, through our approach we aimed at a better understanding of the rural-urban food and water flows and the resulting nutrient and water-related 'urban footprint' or environmental burden. One of our sub-objectives was to analyze the origin of food, differentiated into the contributions from rural, peri-urban and urban areas, and the relationship between food flows and urban diets and consumption. Key outputs, which are hardly found for any other region, are (i) estimates of the magnitude of flows, (ii) an analysis of the generation and fate of solid and liquid waste, and

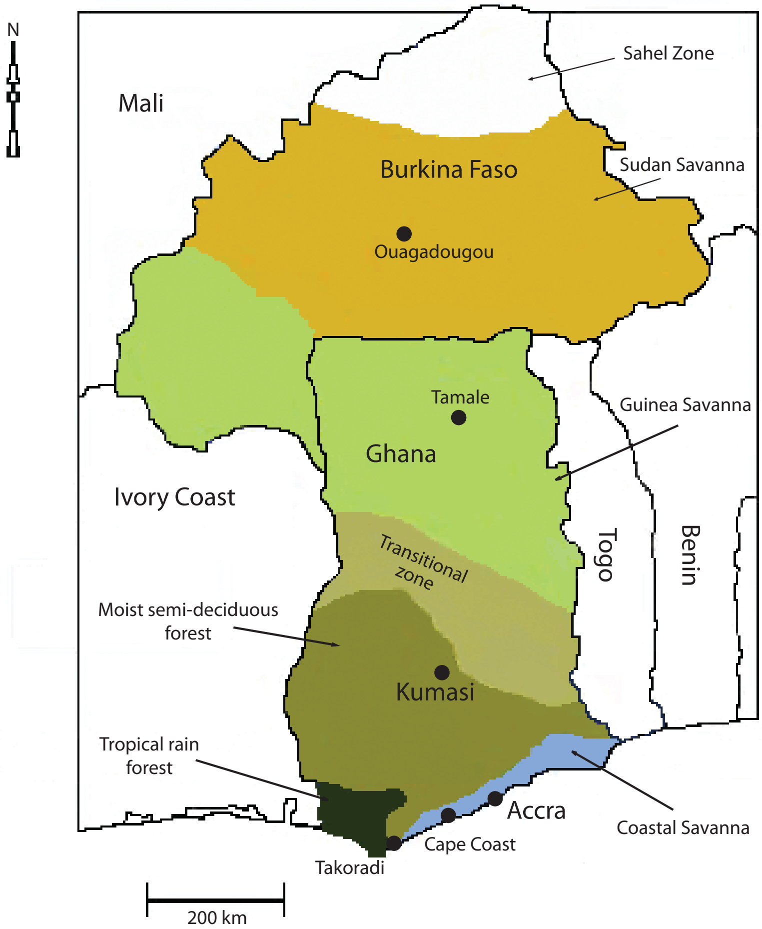
(iii) a clearer understanding of entry points for closing the water and nutrient loops.

The study was carried out in four West African cities: it started in Kumasi, was extended to the Ghanaian cities of Accra and Tamale and finally addressed Ouagadougou in Burkina Faso (Figure 1). The four cities give a cross-section through different agro-ecological zones, i.e., from coast and forest belt to drier savanna areas. All the cities lie, approximately, on the same longitude at intervals of about 200-300 kilometers (km) along the North-South transect.

Accra is the capital city of Ghana and covers an area of about 240 square kilometers (km^2). Within the current administrative boundary, Accra has a population estimated at 1.7 million (Ghana Statistical Services 2002). The population growth rate in Accra is about 3.4 percent annually, which is constrained by the outdated administrative boundary of the city. The actual population growth takes place behind this boundary, where the adjoining districts grew at a rate of 6 to 9 percent from 1984 to 2000. Including those districts, we get the functional boundary of Mega Accra or Greater Accra Metropolitan Area, as the urban dwellers perceive it, with 2.7 million inhabitants and an average growth rate of 4.6 percent (Twum-Baah 2002).

Accra lies within the coastal savanna zone (Figure 1) with an annual rainfall averaging 810 millimeters (mm) distributed over a total of less than 80 days. Within the city boundary, urban agriculture is widespread with about 680 hectares (ha) under maize, 47 ha under vegetables, and 251 ha under mixed cereal-vegetable systems. About 50-70 additional hectares used for food production are distributed over 80,000 backyards (Obuobie et al. 2006).

FIGURE 1.
Location of the cities under study.



Representing the semi-humid forest zone of Ghana, **Kumasi** is the capital town of Ghana's Ashanti Region and the second largest city in the country (Figure 1), with a year 2000 population of about 1.1 million and an annual growth rate of 5.9 percent (Ghana Statistical Services 2002). Daytime population – attracted by Kumasi's large central market - is estimated at 1.5 to 2 million people. Kumasi itself has a total area of 225 km^2 of which about 40 percent is open land. The annual average rainfall of 1,430 mm is distributed over about 120 days. Due to the hilly landscape of Kumasi, most streams run through inland valleys unsuitable for construction but have high value for open-space irrigated vegetable production (approximately 41 ha in the urban area). At least two in three households have some kind of backyard farming. A much higher percentage have at least a few plantain crops or poultry (Obuobie et al. 2006).

Tamale is the capital of Ghana's northern region with a population growth rate of about 2.5 percent. The Tamale district covers an area of about 930 km^2, including the city itself and some surrounding villages, with a total population of 290,000 (Ghana Statistical Services 2002). Tamale lies in the Guinea-savanna belt (Figure 1) with about 1,033 mm of precipitation over 95 days followed by a distinct dry season. Although the Municipality is poorly endowed with perennial water bodies, at least 33 ha close to dams and drains are under open-space irrigated vegetable production, and every fourth household has a backyard with at least a few crops or poultry (Obuobie et al. 2006).

Ouagadougou is the capital of Burkina Faso. The current population is estimated at 1,200,000 with a growth rate of about 6 percent. The city covers about 218 km^2. The major crops grown in the city are cereals while vegetables are grown on about 25-43 ha. The city lies in the Sudan Savanna (Figure 1) with an average rainfall of 880 mm distributed over one season.

Methodology

The study was based on an assessment of rural-urban food flows, and included typical marketing channels, consumption patterns, and the analysis of food flow-related urban nutrient and water footprints in each city. Secondary data on food production, imports and exports, as commonly derived from FAOSTAT in regional or national studies, were not available for the rural–urban comparison. Therefore, the study followed a bottom-up approach based on market surveys for the food flows and household and street surveys to assess consumption patterns.

The markets surveys covered all major markets as well as some smaller but specialized markets and were carried out as far as possible in both the seasons of good supply (peak season) and low supply (lean season) (Table 1). The focus on major markets tried to avoid double counting that would arise from including food flows from one market to the other within the city (Mukui 2002).

The data obtained were analyzed with special focus on the contribution of urban and peri-urban agriculture to urban food supply. "Urban" refers to, in our context, the city boundary, as a satellite image would show it, while the extent of the peri-urban area was analyzed in a separate study according to the outreach of urban services, commuter movement and market access, as described in detail by Adam (2001) (see also Box 1). The area beyond the peri-urban fringe was considered as rural. Imported food was recorded separately. Table 2 shows the different food items considered in the market surveys. Variations in local diets between the cities was given due consideration.

TABLE 1.
Markets surveyed in Accra, Kumasi, Tamale and Ouagadougou.

City	Survey	Markets	Number of traders interviewed	
			Lean season	Peak season
Accra	Main survey	Agblobloshie, Kaneshie, Mallam Atta, '31st December' market, Kokomba	170	200
	Special lettuce survey	Same as above and five smaller community markets, 170 fast-food stands, 26 restaurants	150	0
Kumasi	Pilot survey	Central market, Asafo, Sofoline	85	0
	Main survey	Central market, Asafo, Sofoline, Racecourse	180	240
	Special lettuce survey	Central market, Asafo, Railway wholesale, 12 smaller community markets, 140 fast-food stands, 30 restaurants	160	0
Tamale	Main survey	Central market, Aboabo	240	200
Ouagadougou	Main survey	Baskuy, Boulmiougou, Bogodogo, Nongressom, Sigh Nogin	0	130
Total			1,755	

Also, the main household consumption surveys were conducted during the seasons of good and poor supply. The total number of households that provided feedback can be seen in Table 3. Processed food is generally imported from other countries, and was not considered in the main surveys. The data from Ouagadougou have to be used with caution due to the lower sample size per capita than that in the other cities.

The household consumption survey was strengthened in two cities with data on street food consumption derived from 720 respondents in Accra and 202 respondents in Kumasi.

The results of the market and consumption surveys were used to compute related cropping areas, water and nutrient flows. 'Urban nutrient footprint', in this context, refers to the nutrients exported from rural areas to supply the city with food and other organic materials such as firewood, and the fate of the nutrients in the city. With 'urban water footprint' we refer to the urban water demand in terms of domestic and virtual water[1]. For further details on the surveys see Annex 1.

BOX 1.
Extent of the peri-urban area.

The analysis of the extent of the peri-urban areas concluded on an average radius of 38 km from Accra's city center, with more outreach along the Accra-Kumasi road, and less in between the major roads (Obuobie et al. 2006). This agrees with the delimitation of Kreibich and Tamakloe (1996). A major peri-urban feature around Accra manifests in large-scale pineapple plantations. The peri-urban area of Kumasi was estimated by the UK based Natural Resources Institute (NRI) as being a 40 km radius from the city center (Adam 2001). It is characterized among others by a concentration of larger poultry farms. Also, the peri-urban area of Tamale extends up to 40 km along its major East-West and North-South roads, but only about 15 km in between (Obuobie et al. 2006). The peri-urban area of Ouagadougou was estimated as 30 km on average; the settlements around the city are almost exclusively villages.

[1]With 'virtual water' we refer, in this context, to the amount of water required for the production of agricultural commodities consumed in the cities. See also http://www.waterfootprint.org

TABLE 2.
Food items considered in the market surveys.

Category	Main commodities considered
Cereals	Rice, maize, millet, sorghum, wheat
Tubers and other starchy plants	Cassava, yam, cocoyam, plantain
Fruits; oil	Banana, orange, pineapple; palm oil
Vegetables	Tomato, eggplant (aubergine), onion, cabbage, lettuce
Others (non-crops)	Milk, poultry, fish, meat, egg

TABLE 3.
Sample size (responding households) per city.

City	Number of households		
	Lean season	Peak season	Total
Pilot phase (Kumasi)	91	0	91
Accra	999	983	1,982
Kumasi	950	838	1,788
Tamale	331	463	794
Ouagadougou	0	180	180
Total	2,371	2,464	4,835

Food, Water and Nutrient Flows

Inflow of Food Items to Urban Areas

Approximately 847,000 tons of food is traded in Accra's markets every year (Table 4). The yearly food inflow to Kumasi and Tamale amounts to about 949,000 and 138,000 tons per year, respectively. In the case of Kumasi, this amount requires a standard 7t-transporter entering the city every 2 minutes during daytime, a significant logistical challenge in view of common traffic jams. Based on their weight, staple crops like yam, cassava and plantain form the major part of all food items brought, for example, to Kumasi's markets, reflecting the tuber based diet in the West African forest zone. While cereals are an important part of the traditional diet in Tamale, rice is also increasingly popular in Accra as an urban fast-food component.

Sources of Food Items

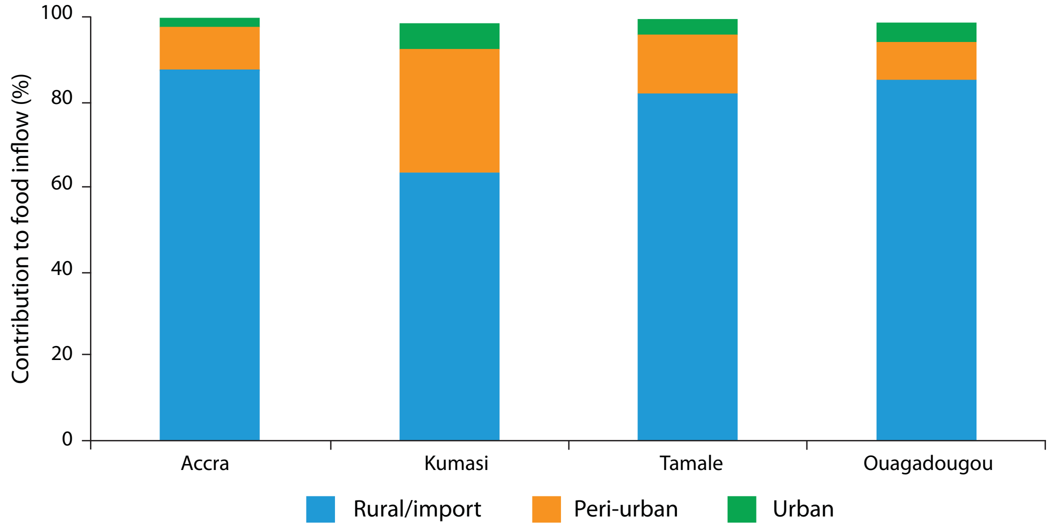
In the four cities, food flows originating from rural areas are the most important overall food sources. Depending on the city, they contribute between 64 and 88 percent of the total inflow to urban areas (Figure 2), with percentages largely determined by the weight of tuber crops.

TABLE 4.
Estimates of inflow of food crops (in tons/year) to three West African cities.

Crop	Accra	Kumasi	Tamale
Yam	141,000	246,700	21,300
Cassava	132,800	213,800	32,100
Cocoyam	42,800	3,400	4,300
Plantain	127,700	144,500	6,200
Rice	107,400	30,000	8,800
Maize	45,500	25,300	20,300
Sorghum	n.d.	n.d.	6,700
Millet	n.d.	n.d.	n.d.
Wheat	30,300	17,600	2,100
Pineapple	59,600	n.d.	5,700
Orange	56,600	n.d.	n.d.
Banana	32,700	n.d.	n.d.
Tomato	24,000	120,900	5,100
Eggplant	17,700	112,200	1,500
Onion	16,900	25,700	21,600
Cabbage	11,400	7,400	1,100
Lettuce	1,250	1,350	n.d.
Okra	n.d.	n.d.	900
Total	847,650	948,850	137,700

Source: this study
Note: n.d. = not determined (in part, as it is not abundant)

FIGURE 2.
Contribution of different areas to urban food inflows on a weight basis.



Source: this study

It is more interesting to differentiate between commodities and seasons (Table 5). For Kumasi a strong seasonality can be observed in the origin of the food supply. Rural-urban food flows are most important (88%) in the lean season. In the peak season, however, peri-urban agriculture reaches an aggregate contribution of 36 percent. It is mainly vegetables like tomato, eggplant and cabbage that are harvested during this time from peri-urban farms. Some of these vegetables, like tomato, are produced in specialized areas or irrigation schemes. Main sources for yam, maize and plantain are the rural areas of Ghana's Brong-Ahafo, Upper East and Ashanti Region. Up to 90 percent of the demand for fresh leafy vegetables, like spring onion and lettuce, is met by inner-city production. Moreover, the lettuce produced in Kumasi is also sold to Takoradi, Cape Coast and Accra (Figure 3). Also, most of the fresh milk found in Kumasi is produced at the local university in the urban area. In the peri-urban areas of Kumasi, large poultry farms produce 80 percent of the eggs found on the urban market while poultry meat is increasingly imported (see below).

The situation is similar in the three other cities in this study, where urban and peri-urban farming supplies certain key commodities, which may not contribute significantly to overall urban food security but do provide a diversified food supply. In Accra, between 900 and 1,000 t of the annually consumed lettuce is derived from irrigated urban fields within and around Accra, whereas approximately 300 t of the total lettuce in the market originates from Kumasi and Lomé (Figure 3).

More lettuce is brought from other cities, especially during the major dry season in Accra. Peri-urban Accra also supplies the city with significant shares of cabbage (50%), eggplant (45%) and pineapple (85%). In Tamale, urban agriculture is important for its cabbage contribution (80%) while peri-urban farming supplies 25-30 percent of rice, maize, yam and sorghum. In Ouagadougou, the supply of urban produced tomatoes, cabbages and eggplant to the city is noteworthy (about 35-45%).[2]

Food **imports** play a strong role in supplying the cities with not only processed food but also

[2]These data refer to open-space farming in the cities. Backyard gardening is another form of urban agriculture, which allows the household to save money otherwise spent on food. Backyard production in Accra and Kumasi involves many commodities, like maize, oil palm, plantain and poultry, but contributes in total less than 5 percent to the overall urban food supply (NRI 1999; Maxwell et al. 2000).

TABLE 5.
Geographical sources of selected food items found in markets in Kumasi during different seasons.

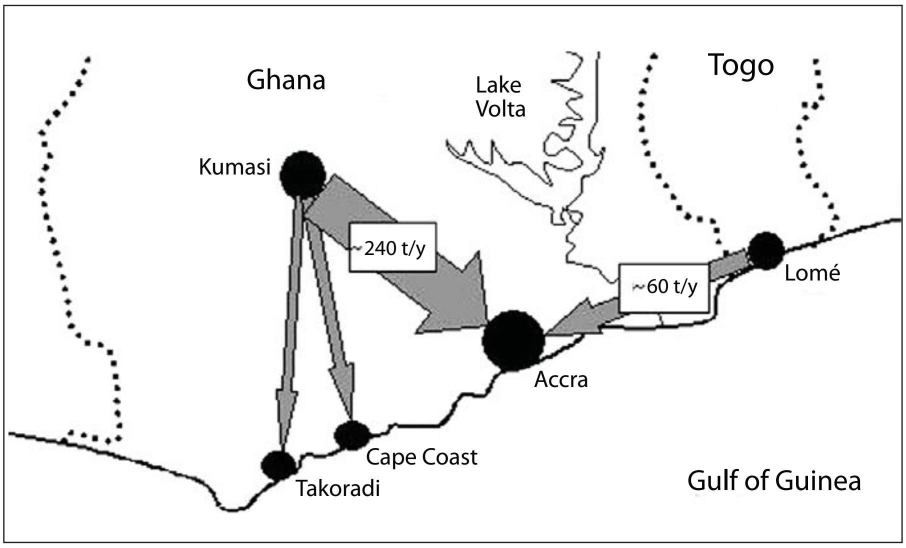
Food	From urban production (%)		From peri-urban production (%)		From rural production (%)		Import
item	Lean season	Peak season	Lean season	Peak season	Lean season	Peak season	(%)
Yam	0	0	0	0	100	100	0
Cassava	10	20	40	70	50	10	0
Cocoyam	<2	<2	<8	<10	90	90	0
Plantain	<5	10	<10	20	85	70	0
Maize	<5	10	5	25	90	65	0
Rice	0	0	0	<5	10	5	90
Onion	0	0	0	10	30	20	70
Eggplant	0	0	0	60	100	40	0
Tomato	0		45		40		15
Lettuce	90		5		0		5
Spring onion	90		10		0		0
Poultry*	15		60		<5		20
Egg	10		80		10		0
Meat	5		10		85		0
Wheat	0		0		0		100
Fresh milk	>55		<25		0		20

Source: this study

Notes: * The share of peri-urban poultry production decreased over the last years due to cheap imports.

certain commodities, such as rice, wheat and poultry. About 20 percent of the average household food demand in Kumasi is met by imports (Belevi 2002) with much higher percentages in the wealthier classes. The large majority (60-90%) of the rice found in Ghana's urban centers comes from Asia and the USA, while onions come largely from Niger, wheat from

FIGURE 3.
Import and domestic trade in lettuce in Southern Ghana.



Source: Henseler et al. 2005

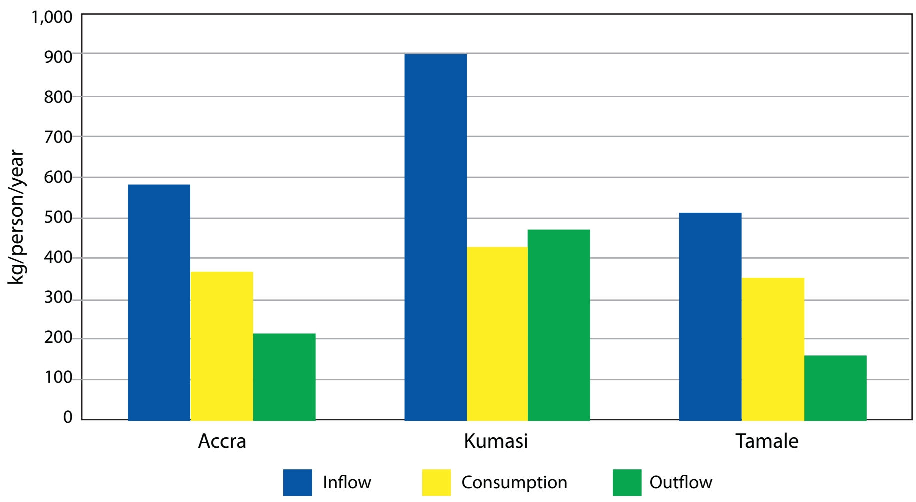
Northern America and frozen poultry meat from Brazil. Ghana's peri-urban poultry industry, which supplied about 95 percent of the domestic demand for poultry meat in 1992, is today approaching less than ten percent (Zachary 2004; Kudzodzi 2006). A similar picture can be found all over Africa, where poultry imports have increased threefold between 1995 and 2002 while prices dropped by more than 40 percent (CTA 2005).

As the food processing and canning industry is little developed, even canned tomato paste is being imported from, for example, China. A survey in different categories of food shops and supermarkets in Accra revealed that the average food item travels 3,700 km by air (SD: +/- 300 km) before it is on the shelf (IWMI unpublished data). A similar survey in New York suggested that on average food items travel about 2,000 km to the city (Smit 2000). Assuming that Ghana develops its post-harvest sector and starts to process at least the food produced in the country, it could reduce its dependency on imports and the average transport distance by 40 percent. An increase in proximity of production to consumption areas would reduce not only transport costs and intermediate storage but also packaging and cooling, which contribute significantly to urban pollution and greenhouse gas emissions. However, it is unlikely that, under given circumstances, the local food processing industry could compete without governmental interventions with the current boom of cheap imports.

Cities as Trade Hubs

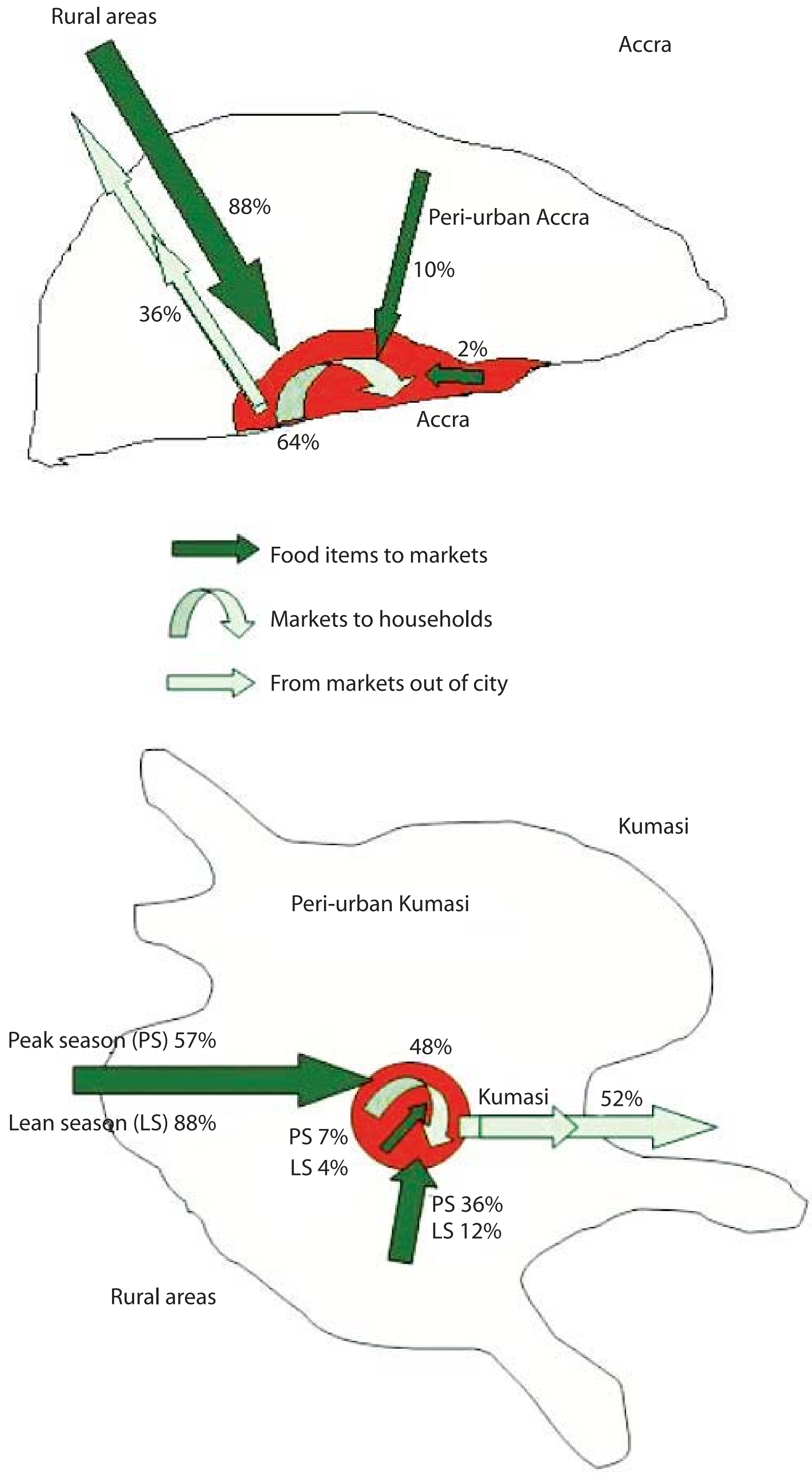
The overall flows of crop and animal products were analyzed in more detail in the three Ghanaian cities. While the proportions of inflow, consumption and outflow are roughly the same for Accra and Tamale, Kumasi has an exceptional status as a central trading center. In per capita terms, Kumasi has much higher food flows than Accra and Tamale. The annual food inflow to Kumasi is 900 kilograms (kg) per person, about 50 percent more than that of Accra and Tamale, while the outflow is 473 kg per person, nearly 2-3 times as high as in the other cities and even surpassing the consumption within Kumasi (Figure 4). These 487,000 tons per year (or 52%) are transferred out of the city to peri-urban and rural markets, to Accra or to other centers, for example, Takoradi (Figure 5). Major commodities that use Kumasi's markets as a hub are yam, cassava, and plantain.

FIGURE 4.
Food flows per person for the case study settlements.



Source: this study

FIGURE 5.
Inflows and outflows of food items in Accra and Kumasi. The data for Kumasi also show seasonal variations.



Source: this study

In contrast, about 615,000 tons per year or 64 percent of the food brought to Accra is consumed within the city, whereas 36 percent is transferred out of the city (Figure 5). The relatively low outflow can be explained by the location of Accra on the coast, as it is a 'dead end' for many national food flows coming from the central and northern parts of Ghana. Cocoa, Ghana's main agricultural export commodity was not included in the flow analysis as it does not pass Accra's markets but goes straight to the harbor at Tema and only a minor part of it is processed in Ghana. This reflects the generally poor development of the food processing sector and hence the dependency on imports.

In Tamale, only 31 percent of the food inflow leaves the city again. Here, one of the largest shares of the outflow is made up of onions from Niger passing the city and tomatoes from Northern Ghana and Burkina Faso.

Consumption

The urban per capita consumption in Ghana varies between 350 and 430 kg/capita/year, which is on average lower than the national figure of 435 kg as estimated by MoFA (2006) from production data. The main difference between the national average consumption and the urban consumption is a shift in the cities to more rice and meat-based meals and fewer tubers and plantain based meals. The difference also reflects a shift to smaller family units and greater convenience in food preparation, as rice-based meals are faster to prepare than the traditional cassava/yam and plantain meals that require hours of pounding.

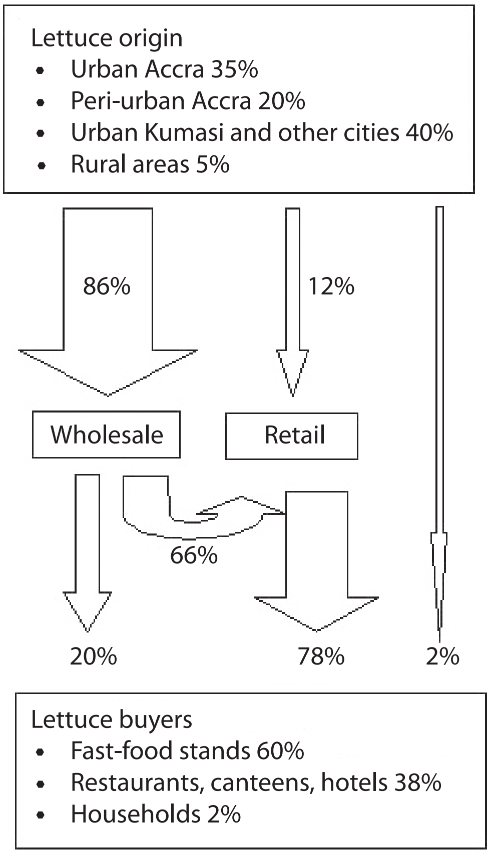
In general, weekly food consumption in the peak season is about 1 to 2 kg higher per AEU[3] compared to the lean season when less tubers and vegetables are purchased. The average protein supply (73-78 g/AEU/day) is sufficient in all the cities, and depends largely on the availability of animal products. The amount of calories consumed (2,107-2,386 kcal/AEU/day) for Accra is lower than that reported by, for example, Maxwell et al. (2000), who considered more prepared (e.g., porridge) and unprepared food items (e.g., fats, beverages) than the present study. In urban Ghana, the average per capita calorie availability (2,269 kcal) is in general lower than in rural Ghana (2,358 kcal) despite lower urban poverty rates (Smith et al. 2006). Urban dwellers are less physically active and more dependent on purchased foods that often have higher prices than in rural areas.

Looking at the vegetable contribution of urban and peri-urban agriculture, the major lettuce distribution pathway from farm gate to customers was studied in Accra and Kumasi (Figure 6). In both cities, the majority of lettuce (60% in Accra and 83% in Kumasi) is purchased by street vendors selling fast-food supplemented with salad, like in 'rice and chicken', from small kiosks. The remaining share goes to restaurants, canteens and hotels. Private households take only about 2 percent in each of the two cities, which reflects the 'exotic' character of lettuce in the West African diet. However, diets are changing, particularly in the cities. In Accra, especially, poorer urban households spend about 40 percent of their food budget and 25 percent of their total expenditure on street food (Figure 7), thereby increasingly adopting a fast-food diet. This is especially the case, when there is no sufficient water or space for cooking and street food becomes a normal coping strategy of the poor (Essamuah and Tonah 2004).

Based on the street surveys, it was calculated that about 200,000 people from all walks of life in Accra consume uncooked vegetables from urban agriculture on a daily basis. If canteens and restaurants are added, another 80,000 beneficiaries of urban vegetable production are possible. Although this contribution does not play any major role for the urban calorie and protein supply, it complements rural

[3]Adult equivalent unit (WHO 1985).

FIGURE 6.
Flow chart showing origin and distribution of lettuce along the farm-to-fork pathway in Accra.



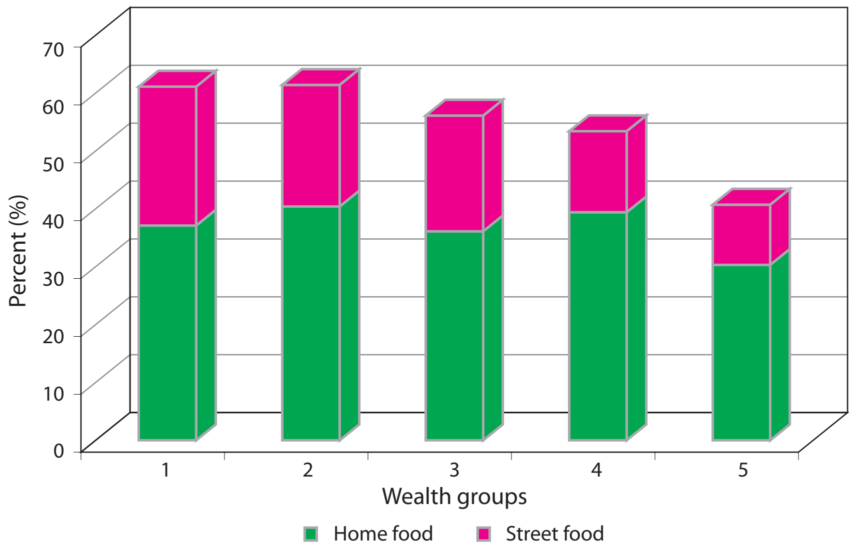
Source: Amoah et al. 2007

production in supplying micronutrients and vitamins. In the study cities, food rich in Vitamin A, such as carrots, local spinach, tomatoes, lettuce, beans, eggs and milk is derived predominantly from urban and peri-urban farms.

Urban Nutrient Footprint

The urban nutrient footprint includes the area needed to produce food and other materials consumed, and the area needed to absorb the waste. Table 6 gives an overview of the areas that are required to meet the demands for major staple crops in the respective cities, assuming average yield levels as reported by the national ministries of agriculture. The data show that about 50,000 to 90,000 ha are required to supply an urban population of one million with the selected crops. Diets based on the relatively heavy tuber crops require less area for cultivation than diets based on cereal staples. Notably, the urban maize supply has the largest urban footprint, i.e., is most space-demanding. This is even more the case where after every second maize harvest another field has to be opened (shifting cultivation), while cassava has lower soil fertility requirements and can be grown for longer periods in most areas. The

FIGURE 7:
Food as share of household expenditures in Accra with increasing household wealth from 1 to 5.



Source: Maxwell et al. 2000

TABLE 6.
Area required to produce the main staple crops consumed in the four cities.

Crop	Average yield (t/ha)	Area (hectares) required to feed			
		Accra	Kumasi	Tamale	Ouagadougou
Cassava	12.3	6,756	6,724	1,919	366
Yam	13.0	6,800	5,308	1,185	977
Cocoyam	6.6	2,909	1,955	500	-
Plantain	8.3	5,373	4,928	470	-
Maize	1.5	37,181	16,376	9,597	38,658
Sorghum	0.8	-	-	-	8,026
Millet	1.1	-	-	-	11,091
Rice	2.3	16,535	13,114	3,114	27,018
Total		75,554	48,405	16,785	86,136

Source: this study

Note: t/ha = tons per hectare

yield data used for rice reflect a Ghanaian average between upland rice (1 t/ha) and paddy rice (4.5 t/ha). However, about 90 percent of the rice currently found in markets in Accra and Kumasi is imported from Asia or the USA, while in Tamale and rural areas the market share of locally produced rice covers about one third of the overall consumption.

Table 7 shows a conversion of the flows of food to the amounts of major nutrients (nitrogen (N), phosphorous (P) and potassium (K)) taken up by the plants and removed with the harvested product. As organic waste recycling (composting) is minimal or nonexistent in the cities and the bulk of the waste ends in the streets, drains or landfills, it becomes evident that urban centers are indeed nutrient ‘sinks’ with significant implications for environmental pollution where waste management cannot keep pace with urbanization (Craswell et al. 2004; Faerge et al. 2001a, 2001b).

The quantity of nitrogen in food that flows annually, for example, to Kumasi, is more than the total amount of all annually imported nitrogen fertilizer in the whole country over the last few years or is equivalent to the nitrogen content of Ghana’s cumulative Ammonium Sulphate imports between 1996 and 2002 as recorded in FAOSTAT (2006).

Urban agricultural production accounts for only 1-7 percent of overall nutrient demand, depending on the importance of urban agriculture in the respective cities. Peri-urban areas do not provide more than 10 percent of nutrient inflows for Accra and Ouagadougou, but provide more than 20 percent for Kumasi and Tamale. Nutrient inflows from rural areas account for more than 90 percent for Accra, 86 percent for Ouagadougou, 70 percent for Kumasi, and 75 percent for Tamale. The corresponding nutrient shift from rural depletion to urban accumulation is shown in Figure 8.

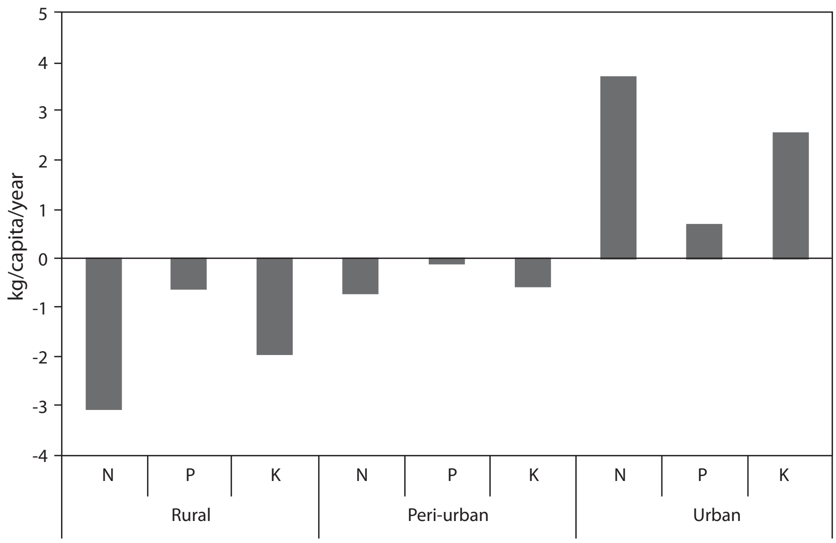
The figures in Table 7 and Figure 8 only refer to the main commodities listed in Table 6. The total N and P flows via agricultural and forestry products entering Kumasi was estimated as being more than twice as high (9,810 t N/yr and

TABLE 7.
Flows of major nutrients from food production areas to the case study cities in tons per year.

	Accra	Kumasi	Tamale	Ouagadougou
Nitrogen (N)	4,318	4,697	813	3,025
Phosphorous (P)	798	559	161	790
Potassium (K)	3,156	4,209	462	1,191

Source: this study

FIGURE 8.
Nutrient balance between exports (negative) and imports (positive) in the rural-urban continuum, averaged per capita for the four study cities.



Source: this study

1,400 t P/yr; Leitzinger 2001). This annual rural-urban nutrient flow has a fertilizer value of US$10 million.

Reducing the Nutrient Footprint

In collaboration with SANDEC[4], a detailed analysis of urban nutrient and water flows was carried out for Kumasi (Leitzinger 2001; Belevi 2002; Erni 2007). The analysis of nutrient flows comprised of food and also other organic materials (timber, fodder, etc.) in order to estimate the total urban nutrient turnover. This 'Material Flow Analysis' focused on those nutrients that do not leave the city via trade of commodities. Key results were (Belevi 2002):

- About half of the total nitrogen and phosphorus ends in groundwater and surface water
- About 22 percent of the nitrogen and 29 percent of the phosphorus are emitted to the soil
- About 15 percent of both nutrients are sent to landfills
- About 15 percent of the nitrogen is transferred to the atmosphere from the households
- Less than 5 percent of the nitrogen and phosphorus end up in faecal sludge treatment plants

Thus, only about 20 percent of both nutrients are retained in the sanitation system, the rest contributes to urban pollution annually worth US$8 million in fertilizer units.

Except for breweries and the timber and poultry industries, (agro)industrial development is at a low level, and private households contribute the majority of organic material fluxes. They also contribute most of the nitrogen and phosphorus emissions (80 to >90%) to the environment through consumption. Therefore, measures taken to support household waste management and collection could greatly enhance resource recovery and environmental protection in Kumasi. Currently, about 18 percent of the generated solid waste (175 t/day) and 66 percent of the faecal sludge (413 m^3/day) remain uncollected in

[4]Department of Water and Sanitation in Developing Countries (SANDEC) at the Swiss Federal Institute of Aquatic Science and Technology (EAWAG).

Kumasi's streets, pits and septic tanks (Mensah 2004; Vodounhessi 2006).

From a technical perspective, part of this environmental load could be recycled through co-composting of faecal sludge and municipal solid waste. SANDEC calculated different corresponding scenarios for nitrogen and phosphorus recovery. In a "realistic" scenario, which only considered the waste currently collected, the entire N and P demand of urban farming could be covered, as well as 18 percent of the nitrogen and 25 percent of the phosphorus needs of peri-urban agriculture in the 40 km radius (see Box 1) (Leitzinger 2001; Belevi 2002). Similar calculations for the other cities would have to consider that, for example, the availability of nutrient-rich organic waste declines towards the Sahel, where it is actually needed most (Figure 9).

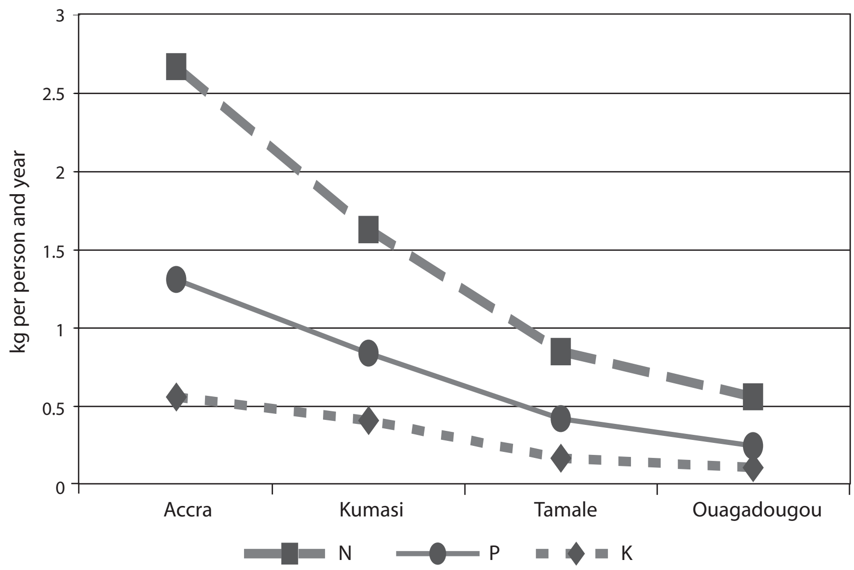
In the realistic scenario the reduction of environmental pollution was less than 20 percent, but could be increased significantly with improved collection capacity. This concerns improved excreta management in particular, since the most significant nitrogen and phosphorus fluxes to soil, surface waters and groundwater occur via faeces and urine transfers (see below). How far such a closed loop concept via co-composting can be realized in practice depends, however, on many economic, institutional and technical factors, which were analyzed comprehensively in a separate project (Drechsel et al. n.d.).

Urban Water Footprint

In the footprint concept everything used along the production chain is taken into account. This integrates the concept of virtual water, which is the water used in the production of an agricultural commodity. The concept gained popularity during studies of the impact of virtual water flows in international trade on global water use (Hoekstra and Hung 2003, de Fraiture et al. 2004) and, more recently, this was extended to analyze water flows between different regions in the same country (Ma et al. 2006).

Thus, not only do rural areas 'export' nutrients but they also 'export' water for the benefit of the cities. In contrast to the nutrients actually taken up by the plants[5] and exported

FIGURE 9.
Nutrient content of collected solid and liquid waste materials across the four cities.



Source: this study

[5]Under fertilization, plants commonly absorb less than 50 percent of the nutrients supplied. Thus, it would be possible to estimate the 'virtual' nutrient needs by factoring the fertilizer uptake efficiency into the calculations. However, in most rural areas in West Africa fertilizer application rates are very low, so in this study the focus was only on estimates of the actual nutrient content of the harvested crop.

TABLE 8.
Virtual water content of annual rural-urban food flows.

Crop	Water demand l/kg crop	Virtual water flows (in 1,000 m³) Accra	Kumasi	Tamale	Ouagadougou
Cassava	407	33,798	33,635	9,598	1,830
Yam	515	45,518	35,529	7,930	6,539
Cocoyam	1,581	30,352	20,393	5,217	0
Rice	3,327	125,414	99,467	23,619	204,921
Maize	2,930	162,349	71,504	41,906	168,796
Millet	3,172	0	0	0	39,726
Sorghum	3,256	0	0	0	19,350
Wheat	1,160	30,332	16,822	2,208	8,442
Cabbage	319	3,632	2,358	350	0
Tomato	758	18,195	23,000	2,200	7,730
Onion	872	11,420	6,452	1,570	6,000
Eggplant	1,163	19,840	23,500	1,345	5,816
Okra	586	0	0	527	0
Fruits, plantain	432	55,470	36,720	5,790	8,950
Total		536,320	369,380	102,260	478,100

Source: this study for virtual water flows; for crop water demand see Annex 1.

from the farm, we look at the water needed to grow the crop, not just the water content at the point of harvest. The flow of this 'virtual water' from farm to city is shown in Table 8. Despite their lower water content, cereals account for most of the crop-related virtual water footprint, where six times as much water is needed to produce 1 kg compared with that required to produce 1 kg of tuber crops. This implies that the water demand within Ghana and water 'imports' will increase with increasing urbanization, taking into account the shift in diets from (rural) tubers to (urban) rice and meat (especially poultry) as described above.

Table 9 shows that compared with the domestic water demand, the virtual water demand is about 40 to 60 times higher. It also shows that the actual crop water content is a tiny fraction of the amount needed to grow the crop. It is also apparent that the water-demanding cereal-based diet in Ouagadougou has much lower actual water content than the tuber and plantain based diets in Accra and Kumasi, especially when we convert the data on a per capita basis. In general, fruits and vegetables show the most favorable (low) ratio between virtual water requirement and actual water content.

The total water demand as shown in Table 9 (2,400 to 3,500 l/capita/day) reflects a more crop-based (vegetarian) diet according to UNESCO-IHE (2006). Comparing the water footprint with the kilocalorie (kcal) and protein supply (not shown here), we can conclude that in the example of Ghanaian cities, for every single kcal an urban dweller consumes, 1.0 to 1.2 liters of water are needed, and for every gram of protein consumed, 30 to 40 liters are needed.

The "urban water footprint" (Table 9), which combines the domestic and virtual water demand, varies from Kumasi to Ouagadougou from 892 to 1,280 m^3 per capita per year, respectively. Roughly speaking, a city of one million inhabitants consumes one cubic kilometer (km^3) of virtual water annually. As irrigation is little developed in Ghana, the large majority of this amount is derived from precipitation. Thus, there is little competition for agricultural water in Ghana and different footprints mostly reflect different diets.

TABLE 9.
Virtual and domestic water demand in the four cities.

	Accra	Kumasi	Tamale	Ouagadougou
Water demand in 1,000 m^3 per year				
Actual water content of crops consumed	310	290	50	70
Virtual water of crops consumed	536,300	369,400	102,300	478,100
Virtual water of animal products* consumed	839,000	399,000	140,000	805,000
Drinking water demand	1,820	1,200	320	1,310
Domestic water demand including drinking water	29,700	19,700	4,000	21,900
Total water demand per capita				
Urban water footprint (m^3/capita/year)	950	892	1,010	1,280
Urban water footprint (l/capita/day)	2,600	2,440	2,767	3,500

Source: this study

Note: * Meat, egg, poultry; excluding seafood.

A possible basis for comparison of the 'urban water footprint' is the 'national water footprint' (Chapagain and Hoekstra 2004), which has been estimated as being 1,293 m^3/capita/year for Ghana and 1,529 m^3/capita/year for Burkina Faso. These estimates, which are based on national production statistics compiled by the FAO and WTO, appear high compared to the survey based data, which is not unusual (Smith et al. 2006). Still, the figures from Burkina Faso and Ghana show a similar difference between both countries as reflected in the urban assessments (Table 9). The reason for the difference could be either the additional consideration of other crops, products and services in the national water footprint calculation, an over-estimation of the national production or deviations through post-harvest losses and the import-export balance.

A particular 'urban' challenge is the consideration of water quality in both the virtual water and urban water footprint concepts. Although water recycling (domestic return flow into the natural system) reduces the urban water footprint, this amount remains marginal compared to the additional environmental water requirements to dilute its contamination load where wastewater treatment is poorly developed (cf. Hoekstra and Chapagain 2007). In the case of Accra or Kumasi, less than 7 percent of the urban wastewater receives some kind of treatment. Most streams passing the cities have faecal coliform loads of at least 10^5-10^6/100 milliliters (ml). Thus, we can assume that every liter of domestic return flow requires 1,000 liters of clean water to dilute its pollution load below the World Health Organization (WHO) coliform 10^3-threshold for reuse via irrigation. In this case, Ouagadougou's urban footprint would increase from 1,280 (cf. Table 9) to 2,144 m^3/capita/year (Figure 10).

Reducing the Urban Water Footprint

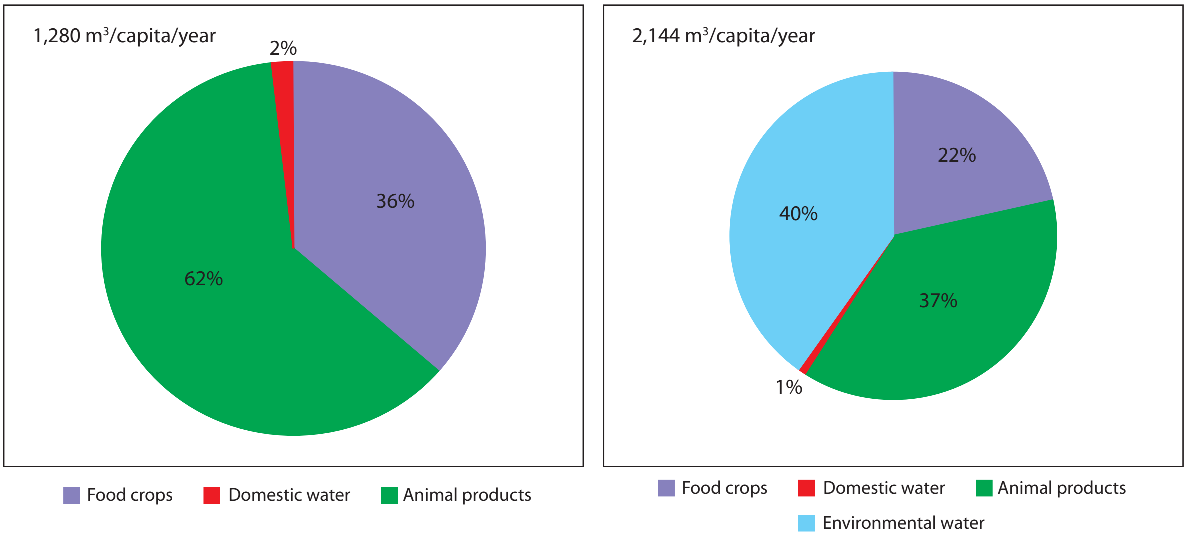
While Accra receives its piped water from two basins, 80 percent of the food-related virtual water comes from four subregional basins and 20 percent (mostly processed and frozen food) comes from 38 basins worldwide, showing Accra's extensive geographical footprint (Table 10) to satisfy urban demands.

TABLE 10.
Basins as sources of domestic and virtual water in the case of Accra, Ghana.

Water type	Number of basins
Drinking water and domestic water	2
Virtual water (unprocessed food)	4
Virtual water (processed food)	38

Source: this study

FIGURE 10.
Consideration of water quality in the urban water footprint concept in Ouagadougou. Diluting wastewater with 'environmental water' (right side) adds a significant consumption factor to the original footprint calculation (left side).



Source: this study

Although there is no possibility to close a 'virtual' water loop, like the rural-urban nutrient loop, i.e., no option to recycle virtual water, there are options to reduce the virtual water footprint. A 5 percent increase in water productivity in domestic rice production, for example, could theoretically make available nearly 5 liters of water per capita per day for Ghana's population. Hoekstra and Chapagain (2007) suggest, among others, shifting production techniques and areas from low to high water productivity. In the southwestern area of Burkina Faso, like near Bobo-Dioulasso, for example, a cubic meter of water allows for the production of about 1.77 kg of dry sorghum grain; in the Sudano-Sahelian central sites (like Ouagadougou), it allows for the production of 0.90 kg; in northeastern Sahelian conditions (like Dori), it allows for the production of 0.32 kg. In such dry conditions, millet naturally competes with sorghum as the staple food crop, as its water productivity remains relatively much higher (at 1.27 kg/m^3) for similar yields (Perret 2006). This reflects a much better adaptation to drought. However, shifting production areas has immense socioeconomic implications, and other possible means of improving water productivity in-situ like rainwater harvesting or no-tillage appear more realistic. However, water productivity is not the only important consideration. As water productivity is lower in Ghana than in Asia and Northern America, the national and urban water footprint would increase if import restrictions were imposed to boost the local rice sector, while the geographical footprint would shrink. As most rice production in Ghana is rain-fed, water is not the limiting factor and fewer imports would support the livelihoods of many rural people in areas that currently cannot compete with imported rice.

Similar to the urban nutrient footprint, another possibility to improve water productivity and reduce the urban water footprint is to improve resource recovery in terms of wastewater treatment and its productive reuse, especially where water is scarce in and downstream of the city. In Accra, irrigated urban agriculture consumes, on average, one liter of the daily per capita grey water production over the year. Thus, urban farming does not compete for freshwater but recycles at least a small fraction of the water that has already been used. This water is, however, treated only in a few cases. Centralized or decentralized wastewater treatment is seldom in place, as sewer networks are usually covering less than 10 percent of the West African city. This might be just appropriate, as piped water is generally in short supply, often cut off for days, and thus would not support the volumes of water required to flush and run any sewerage. So far, the growth of most cities in Ghana and Burkina Faso has been more spread out horizontally, rather than rising vertically, thus allowing on-site solutions, such as pit-latrines and septic tanks.

Erni (2007) analyzed water fluxes in Kumasi and estimated that of the approximately 50 liters (l) used per capita a day, about 40 l are lost in or outside the yard or in storm water drains, about 8 l enter on-site septic tanks and 2 l enter a sewer[6]. Of these 8 l, a maximal 0.5 l is eventually withdrawn with faecal sludge for treatment while the rest leaves the tanks through cracks or overflow. In another assessment, Seidl et al. (2005) estimated overall losses, in Yamoussoukro, Côte d'Ivoire, to be about 85 percent and a maximum of 8 l that might be withdrawn for faecal sludge treatment. Also, in this case, the majority of the black water entering septic tanks was assumed as lost, with the difference being the local frequency of tank desludging. This frequency can be very low and desludging might occur once every 4-10 years in Kumasi.

In general, Kumasi's households return 76 percent of their nitrogen and 48 percent of their phosphorus outputs via latrines and septic tanks to the environment (Figure 11).

The N and P loads to 'soil and aquifer' from human excreta (faeces and urine) are 2,090 and 357 t/yr, respectively. The nutrient loads from excreta to 'surface water' are approximately half the amounts (934 t N/yr and 160 t P/yr). These nutrient loads, together, equal 55 percent of all human excreta produced in Kumasi. In other words, the excreta from 600,000 people are entering the soil and groundwater while the surface water input is equivalent to 270,000 people directly defecating into streams and rivers. Erni (2007) explained this high amount as being due to septic tank overflow and leakage, seepage of latrines and very common open urination. The remaining 45 percent are lost, for example, to the atmosphere (N only) or enter treatment plants. The result of this massive pollution is that the amount of N and P that leaves the city via waterways is over 10 times more than the amount that enters the city in the same surface and subsurface streams and through precipitation (Erni 2007).

The data show that it is important to reduce septic tank overflow and its impact on nearby waterways. Low flush toilets and improved septic tanks with more frequent desludging would have a positive impact on the quality of the combined urban water and nutrient footprint. Dry EcoSan toilets would be most appropriate in suburbs close to waterways and can be cost-competitive compared to other conventional low-cost sanitation options as described by von Münch and Mayumbelo (n.d.) in the case of Lusaka, even without costing environmental externalities.

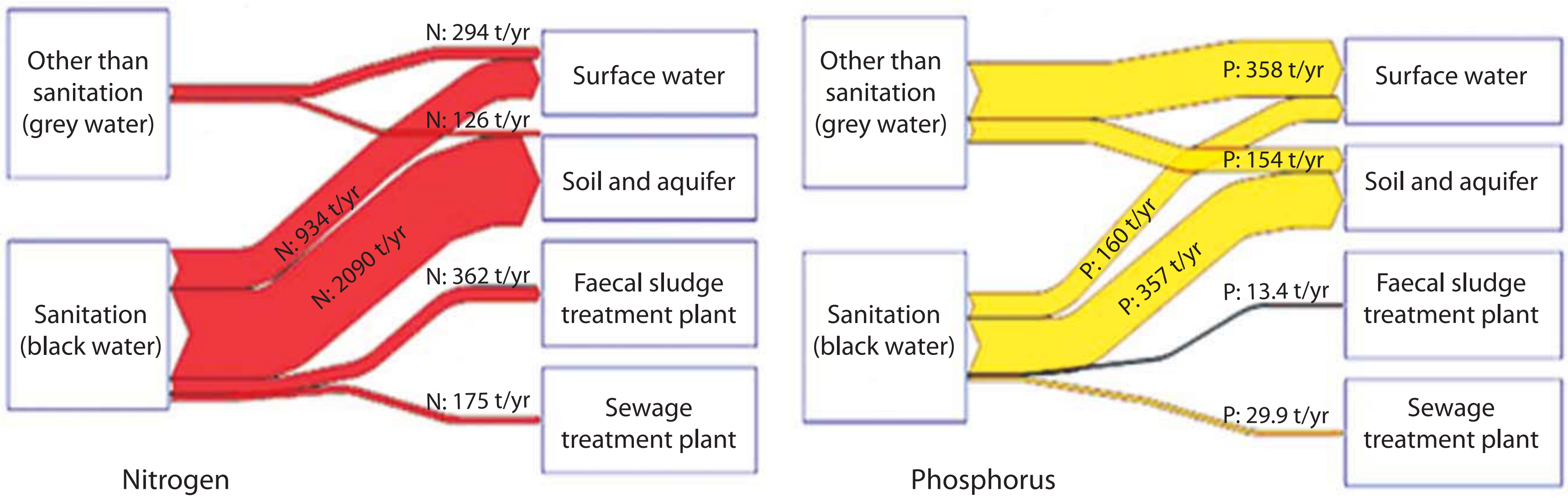
Conclusions

Avoiding the increasing disparity between the urban and rural sectors in a century of urbanization is a major challenge ahead, and it has significant socioeconomic and ecological dimensions. Our analysis of urban footprints in the context of the rural-urban divide was designed to shed more light on this topic.

The present study focused on the urban water and nutrient footprints of key cities in West Africa and highlights the commodity-specific

[6]This is mutually exclusive per household, but on average is valid for all households (about 70 percent of Kumasi's sanitation facilities are dry toilets and 30 percent are water closets; 4 percent of these are connected to a sewer).

FIGURE 11.
Nutrient flows from households in Kumasi. It is assumed that 10 percent of the solid household waste is washed down the drains and was added to the grey water.



Source: Erni 2007

dependency of the cities on agricultural production in rural, peri-urban and urban areas. While the majority of calorie-rich food is derived from rural areas, urban and peri-urban farms cover significant shares of certain, usually more perishable commodities, like vegetables rich in vitamin A and other key nutrients. Many of these food items, like 'exotic' salads, are not part of the traditional diet, but are a key component of the growing urban fast-food or street food sector. In Accra, this sector absorbs, on average, about one third of the household expenditure on food, and appears to be very attractive to the poor. Taking advantage of the increasing demand for rice and chicken dishes, parts of the urban population are increasingly fed by countries like Brazil and Thailand. Although this might save water at the national and global level (looking at differences in water productivity) and thus is a positive externality of international trade (de Fraiture et al. 2004), it also restrains local production and development.

In general, however, cities remain most dependent on rural food supply, which is reflected in the huge demand for cropping area that is needed to feed the cities. With every harvest, the soils in the production areas export some of their fertility while organic residues are not channeled back into the system. Also, the imported nutrients do not redress any decline in soil fertility because the imports are concentrated in the cities (Grote et al. 2005).

However, cities are not only nutrient sinks. Besides the 'urban nutrient footprint', they have a strong 'urban water footprint'. The flow analysis shows that more than 80 percent of nutrients and 95 percent of the water that the city consumes can be considered as lost resources that bypass treatment or recycling but pollute the environment.

There is a huge potential to reuse nutrients and water especially where both are in short supply in the production areas providing food to the cities. The main entry points for better waste management are the urban households where most losses occur. In particular, reduced septic tank overflow and the comprehensive and timely collection and treatment (e.g., co-composting) of excreta would significantly reduce the urban environmental impact.

The burden of the areas producing food for the cities is only compensated for in the vicinity of the city through increased urban services, i.e., the bright side of the urban footprint, including market proximity and higher profit margins of farmers in urban and peri-urban areas (Drechsel et al. 2006). Craswell et al. (2004) stressed the need to include hidden environmental costs as a factor into the debate on rural nutrient depletion and urban waste accumulation. The same applies to the environmental impact of wastewater. The nutrient value, for example, of the uncollected solid and liquid waste (sludge) in Kumasi would be sufficient to pay the service costs of solid waste management for the whole city (US$180,000 per month). About 80 percent of this amount is spent on waste collection and transportation to disposal sites. Waste volume and transport costs could be drastically reduced through composting for the additional benefit of the farming community. A possible financial mechanism for Kumasi has been suggested by Vodounhessi and von Münch (2006).

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Annex 1: Details of the Methodologies Used

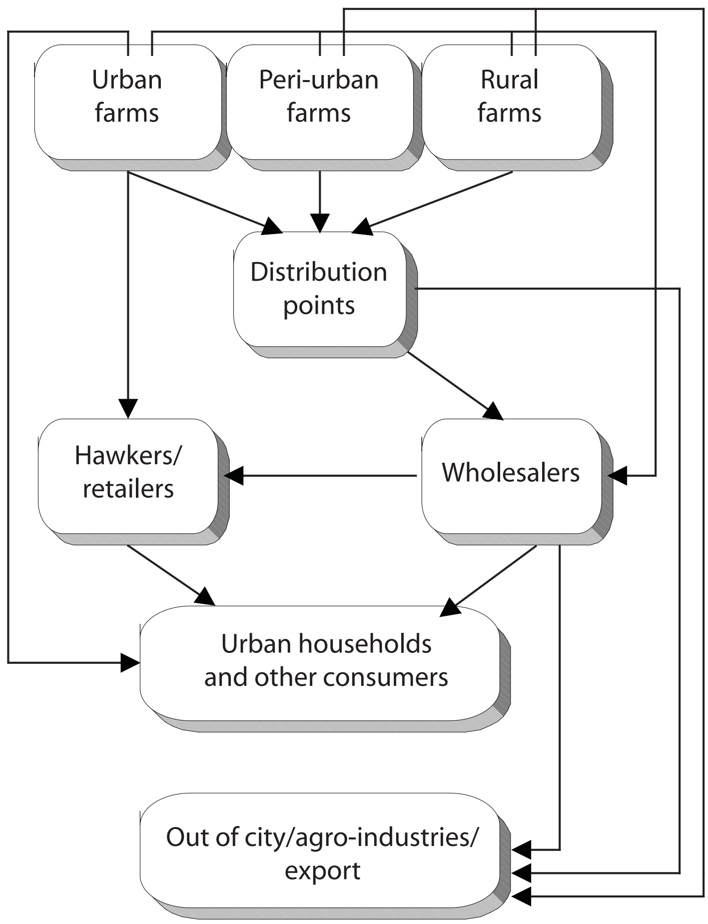
a) Food flows

In order to measure food flows it was important to first get an overview of the various distribution channels (Figure A1) and their individual significance. Interviewing both petty and wholesale traders at different markets, as well as local experts at the universities, was crucial in this regard. The methodology was tested in a pilot study in Kumasi (Leitzinger 2001) and captured data on majority of the traded food.

During the second (main) survey phase in Accra, Kumasi, Tamale and Ouagadougou, traders were targeted. Besides all larger markets, smaller (specialized) markets were surveyed for certain crops (Table 1). Care was taken to avoid double counting between wholesale and retail markets. At every market, depending on its size and the commodity, five to twenty randomly selected traders were interviewed per crop.

When appropriate, the traders were stratified into small, medium and large business entities to make them as representative as possible. When possible, in-depth interviews were conducted with the queen mothers[7] as they keep detailed records

FIGURE A1.
Food flows selected for the market survey.



[7]A market queen mother is a lady who acts as the leader of a group of market traders, controlling either the whole market (smaller ones) or a certain range of commodities (in larger markets) or only one major commodity like yams.

of sales, which can be more reliable than calculations based on individual traders.

Traders were asked to provide information on the production area or distribution point from where they receive their produce, and the quantities they buy and sell. Wholesale traders also estimated the share of food items sold that are leaving the city again. Daily turnover was cross-checked via the day-to-day balances of traders, while city outflows were compared with the differences between inflows and household purchases for consumption. All the data obtained were converted to fresh and dry on a weight basis. Table 2 shows the different food items considered in the market surveys. Adaptation to local diets in the various cities was given due consideration. Food flows were measured over one week per season, in both the seasons of good supply (peak season) and low supply (lean season). The supply peaks differ from crop to crop and between regions with unimodal and bimodal rainfall patterns. In general, it appeared that after the harvest from September to March and again in June/July more produce is on the markets, while the lean season lasts from April to August. In Tamale and Ouagadougou, the lean season is longer as the onset of the rain takes place much later. Based on the number of weeks representing good and poor supply, the results of the lean and peak season were extrapolated for the year.

As the sample size in Ouagadougou had a relatively lower per capita than that in the other cities, we used that data only with caution.

In a third phase of the project, special attention was given to lettuce, which represents a typical product of urban agriculture. This phase was carried out only in Accra and Kumasi, targeting main and neighborhood markets, restaurants and fast-food stands from a stratified subset of high, middle and low income suburbs (Henseler et al. 2005). In markets, daily lettuce in- and outflows were quantified and analyzed through observations and interviews with sellers and buyers. The identification of the lettuce consumption group was based on interviews and observations of daily fast-food purchasers as well as total lettuce turnover and the average amount (fresh weight) in different food items.

b) Food consumption

Household food consumption

The household food consumption survey was initially devised as a control for the inflow–outflow balance in the food flow surveys, but eventually appeared to be of a higher accuracy than the market surveys covering nearly 5,000 households or about 30,000 urban dwellers. Thus, the city food outflow was calculated by subtracting the consumption from the inflow.

To reach a large number of households, the questionnaires were distributed through the educational sector to schoolchildren in junior secondary schools (ages 13-16) and explained in detail. The children were asked to take the questionnaires home and to note the amounts of the 24 most common food items consumed for one week. These common food items were identified in the pilot run, with due consideration given to the regional preferences. At the same time, qualitative questions on related fields (sanitation, urban agriculture, waste management, water supply, etc.) were included. The approach was successfully piloted in Kumasi as women in most households kept an exact record of their purchases[8].

The schools were randomly selected from the different sub-metros in each city. The number of schools in each sub-metro was determined to reflect population proportions. Care was taken to keep the study representative in view of different religious groups, e.g., through the inclusion of Islamic schools. Data were collected for households that might not be able to send their children to school by undertaking door-to-door surveys in low-income sections of the city.

[8]Financial reporting to their husbands.

The main surveys were conducted in both seasons, using the same schools and classes to maintain comparability (Table 3). In general, processed food was not considered. All results were fed back to the classrooms.

In Ouagadougou, only one survey could be conducted during the transitional period from the good supply season to the lean season (end of February).

All household data were collected in monetary terms (e.g., 'cassava for 2,000 cedis') as it was easier for the households to quantify their consumption that way. Therefore, the first step of analysis was to convert the data into weight terms. To provide data per capita, the concept of 'adult equivalent units' (AEU) was used to make comparison independent of differences in the age structure of households (WHO 1985).

Street food consumption

An important feature of food consumption in Ghana is street food, sold by hawkers and in 'chop bars' or canteens, which can be found almost everywhere in Ghanaian cities. In Accra and Kumasi, most people, from schoolchildren to students, laborers and office workers, eat at their place of study or work at least once a day, around noon. Others eat outside in the evening. In Ouagadougou, on the other hand, common lunch breaks last 2-3 hours to allow an extended lunch at home as the main meal of the day. In Ouagadougou, no additional street food survey was carried out.

Guided interviews were conducted at the eating-places in the city centers, such as so called 'chop bars', restaurants and with people buying fast-food from moving vendors. As for the household survey, respondents were asked to list all the food items they consume in public places for one week. We focused on four main dishes (Kenkey, Banku, Fufu, and rice/chicken) with known amounts of ingredients. The sample size for the survey was 720 respondents in Accra and 202 respondents in Kumasi. As the surveys were conducted in the city centers, the respondents represented the economically active part of the population rather than the whole urban population. To provide for this, the ratio of the economically active people to the whole urban population was applied (ca. 50%) to adjust the results to be representative of the whole urban population (Ghana Statistical Services 2002).

The street food consumption values were incorporated into the household consumption figures, i.e., all statements and conclusions on amounts, nutritional values, etc., refer to the total consumption. To assess the overall quality of nutrition, the food items consumed were also re-calculated in terms of energetic value (kcal) and protein content per AEU.

c) Food chain survey

To assess the marketing chain of an urban produced crop, we took lettuce as an example, and surveyed the major transition points where lettuce was sent to or received in Accra and Kumasi. In Accra, six main markets and five neighborhood (or community) markets were surveyed, whereas in Kumasi the three main markets and 12 neighborhood markets were included in the survey. At the markets, sellers and customers were interviewed. For each market, general information was gathered on the origin of the produce, average price per sack and total number of wholesalers and retailers at that particular market. Representative sacks used to transport lettuce were weighed.

In order to follow the distribution chain of lettuce, it became necessary to carry out a further survey among fast-food sellers. As part of this study, 133 and 244 stands were visited in Accra and Kumasi, respectively. As not all serve lettuce, 83 fast-food vendors were interviewed in Accra and 144 in Kumasi. Likewise, 161 and 212 fast-food customers were interviewed in Accra and Kumasi, respectively (Henseler et al. 2005). The number of fast-food sellers in Accra selling food known for its lettuce supplement was estimated based on the statistics of the Accra Municipality and Ghana's Food Research Institute. About 90 fast-food vendors in different parts of the city were visited at different times on a day and the absolute number of people who buy food with lettuce per day (in contrast to other food or the same but without lettuce) was recorded. For control, the average weight of lettuce per fast-food meal was measured and the corresponding number of units calculated based on daily (Accra internal) wholesale turnover.

d) Geographical extent of the consumption footprint

In contrast to markets, food shops and supermarkets sell mostly packaged and processed food, but also contain fresh products. To get an impression about the origin of food, in the example of Accra, we stratified the common food shops into three categories (supermarket, shop, and kiosk) and visited representative stores. For each category of food (e.g., canned tuna), the available brand names and country of origin was recorded. The results were weighted per country and the average distance calculated for a product traveling to its shelf in Accra. This was the only survey that considered processed food.

e) Virtual water and nutrient footprints

The results of the market and consumption surveys were used to compute related cropping areas, water and nutrient flows. The urban water footprint was estimated through aggregating the individual water footprints of the urban dwellers based on the quantities of food consumed. The virtual water content, i.e., the amount of water required for producing a unit of crop in m^3/ton was calculated according to Hoekstra and Hung (2003). Food water requirements were computed from the IWMI 'World Water and Climate Atlas' (http://www.iwmi.org/WAtlas/atlas.htm). Data for animal products were extracted from http://www.waterfootprint.org and Zimmer and Renault (2003).

Domestic water demand per capita per day was estimated as 38 liters in Tamale and 50 liters in Accra, Kumasi and Ouagadougou (London Economics 1999; Ouedraogo 2003). The food flow related 'urban nutrient footprint' is based on the crop nutrient content using data provided by Stoorvogel and Smaling (1990), Kroll (1997) and Schippers (2000). Local yield levels for the calculation of required production areas were taken from ISSER (2003).

f) Limitations of the methodological approach

All assessments presented are based on the empirical analysis of food flows and consumption. This is a complex task with many possible error sources.

City level (food flows): the market survey captured all major food crops that pass urban markets, but did not count trucks passing through cities without unloading. The quantitative assessment also did not capture food bypassing regular market chains or the import of most processed food, e.g., for supermarkets. In contrast to the household survey on consumption, the market surveys focused only on food crops. It did not cover slaughterhouses. Despite all efforts, the food flow assessments have an estimated 20-40 percent error margin. The margin is smallest in Kumasi - where the flows were analyzed in both seasons (lean and peak) and in different years - followed by Accra, Tamale and finally Ouagadougou.

Household level (consumption): based on the school approach, the household survey only captured households with children in junior secondary schools. According to the Ghana Statistical Services (1999) this situation applies to a representative 40 percent cross-section of the urban population. The different foodstuffs in the household survey had to be limited to the 24 most common items, as otherwise the effort of filling questionnaires would have become too cumbersome for the families. Calorie providers that were not sufficiently covered by the survey include snacks purchased as street food, bread, groundnuts and other fats and oils other than palm oil. Another limitation is that households only noted food that is commercially acquired, but not food that is brought by family members from farms in or outside the city. Our surveys on urban agriculture indicate that despite their frequency, most backyards are very small and the amounts produced are low (Obuobie et al. 2006). Food supply through own production, gifts and transfers equaled less than 10 percent of Accra's average household expenditure on food (Maxwell et al. 2000). As mentioned above, the sample size in Ouagadougou was less extensive than that of the other cities. Thus, the consumption data should be used with more caution. Finally, there are two populations in many urban areas: the night population and daylight population. The night population is normally enumerated in population censuses and household-based surveys. The daylight population includes, in addition, people from adjoining areas who regularly commute to the city during working days for work or school. The daylight population contributes to the urban food consumption, which was in part considered through the street food survey, but not when extrapolating results to the city level, which could only follow the data provided by last census. There are no reliable estimates of urban daylight populations.

Virtual water and nutrient flows: Most limitations described above also affect the calculation of the water and nutrient flows. Additionally, the assessment is based only on food consumption and domestic water use, but does not consider virtual water related to industrial goods and services, like the local textile industry. These are, however, only of marginal importance in both countries compared to the consumption of agricultural goods (Chapagain and Hoekstra 2004).

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International Water Management Institute

IWMI is a Future Harvest Center supported by the CGIAR

ISSN 1026-0862
ISBN 978-92-9090-669-8