7. Irrigation and Soil Fertility Management Practices

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This chapter describes the different irrigation methods and nutrient application practices used by urban vegetable farmers. Data are based on surveys conducted in Kumasi, Accra and Tamale. Recent relevant publications are also reviewed.

7.1 Irrigation Systems in Ghana

Namara et al. (2010) generally classified irrigation systems in Ghana into two types: conventional (public) systems, which are mainly initiated and developed by the Ghanaian government or various NGOs, and emerging systems, which are initiated and developed by private entrepreneurs and farmers. Irrigation systems in urban and peri-urban areas are generally managed by smallholders and fall under the emerging informal irrigation systems, although there can be exceptions, like the Ashaiman scheme (see 2.2.1 and chapter 13).

A survey done in 2003 shows that Ghana's 22 public irrigation schemes have a developed area of 8,785 hectares (ha), with the area under actual irrigation being about 5,200 ha (Miyoshi and Nagayo 2006) with annual and seasonal variations. However, little is officially known about emerging systems, but they are expanding at a rapid rate, mainly fuelled by access to relatively affordable pumping technologies and to urban or export markets for horticultural crops. It is difficult to establish the extent of area of the emerging systems, but it is believed that the area is much greater than that of the conventional/public irrigation systems (Namara et al. 2010). For instance, two 3.5 HP (horse power) pumps, communally owned by 100 farmers irrigated about 20.1 ha in Ashanti. The corresponding value for two small reservoirs, Tanga and Weega, in the Upper East Region was 7.7 ha serving about 314 farmers. This informal urban and peri-urban irrigation sector is common across Africa and was described in detail for West Africa by Drechsel et al. (2006).

7.2 Sources of Irrigation Water in Major Cities

As described in the previous chapter 6, sources and quality of irrigation water vary from using clean piped water to the use of untreated wastewater. Most common is, however, the use of stream and drain water, highly polluted with untreated domestic wastewater. A brief overview of some key features in Accra, Kumasi and Tamale is presented here:

In **Accra**, the main sources of irrigation water are urban storm water drains and polluted streams. The content of these natural or human-induced drains varies from raw wastewater as in Korle-Bu to storm and graywater, often with high fecal contamination (open defecation, flying toilets), though the dilution changes between locations and seasons. In Dzorwulu, a polluted stream (Onyasia) is used, supplemented by pipe-borne water. Other than using a big gray- and stormwater drain that runs through Accra's La area, a few farmers there also use raw wastewater from a punched sewer pipe or partially-treated effluents from ponds of the largely dysfunctional wastewater treatment system belonging to the Burma Military Camp.

In **Kumasi**, larger areas under informal irrigation can be found in the inland valleys passing the city where shallow wells, dugouts and polluted streams are the main sources of irrigation water (Figure 7.1). About 70% of farmers interviewed use polluted streams. None of the farmers interviewed used untreated wastewater or effluents directly from treatment plants. Very few cases (n< 5) were reported where farmers, because they have no choice, use wastewater from drains. There is extensive use of shallow dug wells on valley bottoms (27%), especially in the urban area. Of the 70 farmers interviewed, more than 75% said that they use the source of water that is accessible and reliable. Piped water is not only expensive but also often not flowing, if there is an access point close to the fields which is seldom.

FIGURE 7.1. Typical irrigated urban vegetable farming system in Kumasi (photo: IWMI).

In **Tamale**, with no perennial stream and a long dry season, water is scarce, and farmers use water from reservoirs, or have to choose between free water from open drains, water from stand pipes or costly piped water. A common source is graywater or wastewater from urban drains or dysfunctional water and sewage treatment plants, like the Kamina barracks, while for example at 'Waterworks', Choggu, Builpela or Dabogpa farmers use water from dammed reservoirs (Table 7.1).

TABLE 7.1. Water sources in different irrigated areas in urban and peri-urban Tamale.

Farm location	Farmers’ water sources
Gumbihene Old Dam	Treated tap water
Gumbihene New Dam	Standpipe/well
Gumbihene Waterworks	Canal/drain
Choggu Dam	Reservoir, standpipe/well
Sangani	Dugouts
Nyanshegu	Standpipe/well
Kamina Barracks (Zagyuri)	Wastewater
Builpela Dam	Reservoir
Tunayili	Standpipe; polluted stream; reservoir
Jekeryili	Polluted stream; reservoir
Dabogpa (Ghanasco Dam)	Reservoir

Note: Information from July 2014 (IWMI, Ghana, and Lea Bartels, University of Freiburg; unpublished; UrbanFoodPlus).

7.3 Irrigation Methods Used in Urban Vegetable Farming

7.3.1 Watering Cans

This is the most common irrigation method used in all the study areas (Keraita et al. 2007a). It is also the most precise one for fragile leafy vegetables. When using watering cans, water is fetched manually from nearby water sources and applied on the vegetable plant (overhead) using the same watering cans. It is common for farmers to fetch and apply water using two watering cans simultaneously (see Figure 7.2). As men dominate irrigated urban farming, it is rare to see a woman with two watering cans. In peri-urban areas, where more women are involved in irrigating vegetables, the use of buckets, carried as head loads is common. One watering can as used in Ghana has a capacity of 15 l of water.

Almost all farmers in the valley bottom of urban Kumasi use watering cans. Most of them have shallow dug wells on their farms and even for those who have to fetch water from streams, the distance is usually short (15 to 25 m). Previous studies (Keraita 2002; Cornish et al. 2001) showed that in an attempt to make leafy vegetables look fresher, farmers closer to water sources tend to over-irrigate leading to leaching of soil nutrients and increased contamination of crops as sources of irrigation water are polluted (i.e. they use more water than crop water requirements).

FIGURE 7.2. Lettuce irrigation with watering cans in Accra (photo: IWMI).

7.3.2 Bucket Method

In this method, bowls and buckets are used to fetch water, usually from various sources of water, but mainly streams, shallow wells and dugouts. The water is then manually carried in the bucket to the fields where it is either applied directly or put in a drum, for example, to be applied later. This practice mostly involves women and children carrying buckets as head loads and is commonly carried out in peri-urban areas. Here male farmers involve family members and take advantage of the traditional role of women and children in carrying water. Farms are comparatively further away from the water source than the ones where watering cans are used, but normally not beyond 200 m.

7.3.3 Small Motorized Pumps

Vegetable farmers in Ghana are increasingly using small motorized pumps to lift water from water sources like shallow wells and streams (Figure 7.3). Most motor pumps have an engine capacity ranging from 3.5 to 10 HP (Namara et al. 2010). Based on a survey conducted in 2009, which found 170,000 petrol and diesel pumps and 5,000 electric pumps in use, Namara et al. (2014) estimated that on average 12% of the 1.85 million farming households in Ghana own a pump.

FIGURE 7.3. Farmer using a small motorized pump irrigating from an on-farm pond (photo: B. Keraita).

Pumps are not fixed in the fields but taken home over night. In the field, they are placed near a water source, usually the bank of a stream or near a shallow well and water is pumped through rigid plastic pipes or semi-flexible pipes which are connected to a flexible hosepipe at the end. Farmers use the hose pipe to apply water to their crops either overhead or near the roots on the surface, depending on the crop. In other cases, pumps are only used to lift water from a deep water source and pump it to a water reservoir or pond in the farm, from where irrigation is done using watering cans.

In many cases where motorized pumps are used in Ghana, especially in peri-urban areas, there are often water losses from leaking pipes and the use of pumps of higher capacity and pipes of larger sizes than required is common. Although the use of pumps is reducing the frequency of farmers stepping into the main water source to fill the cans, occupational water contact remains common when farmers try to fix pumps, pipes and direct the water hose to apply water in the field. The fields are usually adjacent to the water sources and the pipes could be as long as 300 m infield. Whenever this method is used to irrigate fragile vegetables and nurseries, a perforated cap (like a shower head) is placed at the end of the pipe to slow water delivery to the crop and prevent physical crop injuries. However caps reduce irrigation speed, so for mature crops and crops that grow tall like garden eggs and green pepper, the caps are removed to hasten watering.

A typical small motorized pump used by farmers in Ghana costs USD250 to 400 while farmers who hire the pumps pay between USD5 to 10 per day. The additional cost of accessories like tubes which can cover one ha are estimated at USD 270. The final cost being influenced by location, HP of the pump, the model/brand of the pump and the size of the cultivated land.

7.3.4 Surface Irrigation

Gravity irrigation, mainly through furrows is being practiced in La in Accra. The La farming area is a comparatively larger open space with sloping topography that allows for furrow irrigation. The source of water is an open drain from the nearby army camp. Some farmers have constructed an open weir and diversion channel to irrigate their plots downstream by furrows (fruity vegetables like tomatoes), while others divert water into dugouts from where they can fetch water with a watering can (leafy vegetables). During the dry season, farmers raise the water level in the drain with sand bags and divert the water in the main canal, which conveys the water to the plots. In these furrow systems crops are less exposed to contamination as they are grown on ridges. However, low-growing crops are also cultivated and even higher-growing crops like tomatoes, if not staked, can have contact with irrigation water and wet soil if they incline to the ground. Exposure to farmers is also high as they have to block the drain and direct water in the furrows.

7.3.5 Sprinkler and Drip Irrigation

Both systems are not common methods in urban farming and sprinklers were observed only in locations where farmers have access to pipe-borne water. Cheaper PVC pipes and low cost materials like bamboo were used as sprinkler risers and to make delivery pipes. The systems were not fixed and farmers using sprinklers used watering cans as well. The fields irrigated were larger than those used by other methods but the crops grown were the same. When wastewater is used, sprinkler irrigation though modern, can increase risks both on farm (water applied directly on crops) and off farm (aerosolized particles affecting farmers and the environment).

Drip irrigation systems have been introduced by different institutions, also for vegetables, and are occasionally observed in urban and peri-urban settings, albeit so far at experimental levels introduced for example by the University for Development Studies (UDS) in Tamale. Adoption by farmers has been poor up to now. The systems require a storage reservoir and many farmers are reluctant to install any infrastructure on their plots as long as their land tenure situation is weak and only of informal nature. Another challenge was the wide spacing of the holes, which did not support the required cropping density of lettuce for instance (see below).

7.4 Productivity of Irrigated Urban Vegetable Systems

Amounts and Frequency of Water Application

Leafy vegetables, which are the most commonly grown crops in irrigated urban agriculture, have higher and more regular crop water requirements compared to more traditional crops. According to Agodzo et al. (2003) irrigation water requirements of most vegetables grown in Ghana vary between 300 and 700 mm depending on the climatic conditions and crop species. As the extension service has limited training to support informal irrigation, farmers have learned over time when and how much water to apply to their crops. When asked a question like "How do you know the amount of water to apply?" most urban farmers indicated 'hands-on-experience' mostly using soil, crops and weather as indicators (see Figure 7.4).

Generally, across Ghana, most farmers irrigate in the mornings and evenings, saying that at these times "It is cooler so we can more easily carry the water-load" which corresponds well with periods of low evapotranspiration rates, allowing other farm tasks like weeding to be done during normal working hours (8 am to 5 pm). Irrigation is also done in the rainy season on days without rain as especially the exotic lettuce responds quickly to water shortage. In other countries, like Ethiopia, with a more moderate climate, urban vegetables like lettuce and cabbage are only irrigated about three to four times a week in, for example, Addis Ababa.

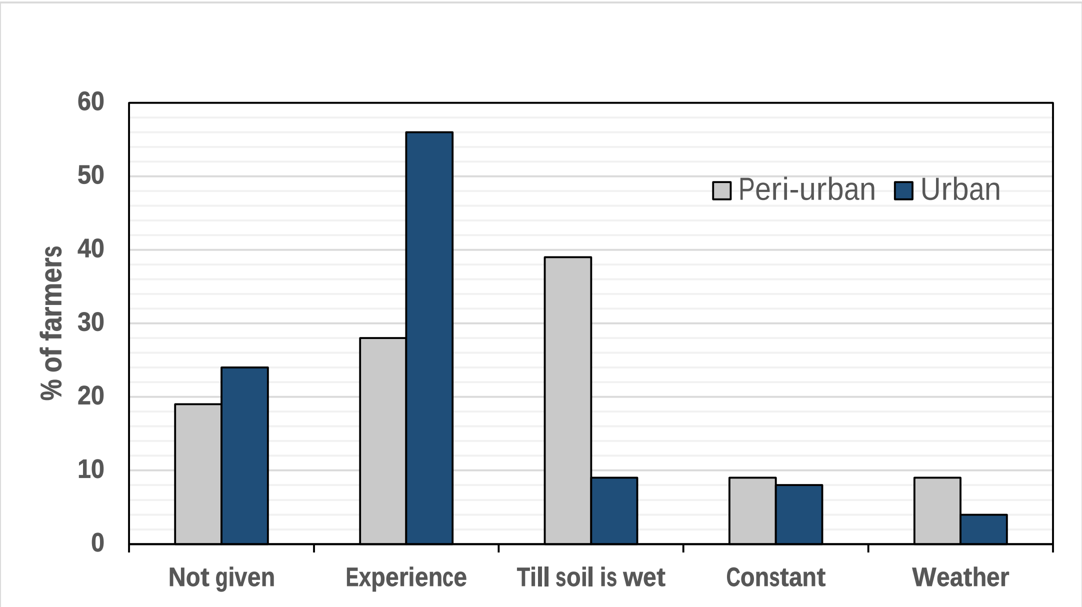

FIGURE 7.4. How farmers know the correct amount of water to apply.

Not all farmers can afford to buy irrigation equipment, like motorized or electrical pumps. However, pumps can be rented for different time periods (Namara et al. 2014) and also neighborhood arrangements can enable farmers to hire pumps on affordable terms. At Dedesua, near Kumasi, for instance, most farmers only pay for the fuel of a local motor pump. Payment can also be made on flexible terms such as paying after selling the crop or by providing labor for the pump owner. Some farming sites have farmers' associations to exchange labor and irrigation equipment.

Field observations on irrigation showed a tendency to over-irrigation in urban areas by about one-third of the irrigation water requirements and a likely under-irrigation of the same magnitude in peri-urban areas, although such estimates are difficult as cops and soil texture often differ. Given their generally smaller farms, urban farmers achieve a more uniform spatial water distribution than peri-urban farmers because of the watering cans, and their regular irrigation intervals. The irrigation rate varies depending on soil, crop and weather, with 5-7 litres/m^2/day as a first proxy for the dry season, but rates can also be twice as high.

Farmers in peri-urban areas who depend on the availability of pumps, have often irregular irrigation intervals and poorer water distribution, especially those using hosepipes. In peri-urban areas, only few peri-urban farmers own a pump, so farmers hiring pumps often wait for long periods before irrigating their farms while queuing to hire a pump. Subsequently it is quite common among these farmers to apply as much water as they can when the pump is available as they do not know when the pump will be available again. In addition, when payment for the pump is done on a daily basis, there is a tendency to over-apply that day assuming that this caters for the other days, so as to maximize the benefit on the money paid for hiring the pumps. In Dedesua (see above), to reduce renting costs, farmers on average irrigated once in three weeks instead of once a week over a 120-day crop growth period of local vegetables like *ayoyo* and *alefu*. These indigenous vegetables have significantly lower water requirements than exotic ones. Farmers felt that this was sufficient for the crops but in reality such long intervals could affect crop productivity.

Productivity of Different Irrigation Methods

Keraita et al. (2007a) compared three irrigation methods – furrow, low-head drip kits and the conventional watering cans under actual field conditions during the dry and wet seasons on irrigated urban vegetable farms in Kumasi. Different farmers volunteered to compare the three methods, each using their expertise on the amount of water needed which is based on a mix of observations (weather/soil/crop). Furrow irrigation resulted in comparatively much lower fresh weights, both per plant and per area, especially during the dry season, compared to drip irrigation and watering cans methods (Table 7.2). The differences in fresh weights were statistically different in both seasons. The differences were more pronounced in the dry than in the wet season when rainfall supplemented all the methods equally. While drip irrigation plots had higher fresh weights in terms of weight per lettuce plant by 7 to 10%, its production per given area (kg m^{-2}) was slightly lower than under watering cans plots due to a lower cropping density of 13 versus 15 lettuce plants m^{-2}.

The common water productivity of lettuce varied between 10 and 15 kg m^{-3} depending on cropping density, irrigation method, season and soil. Furrow irrigation with a low planting density of 10 lettuce plants m^{-2} and a sandy soil had also the lowest water productivity of 3 to 4 kg m^{-3}.

TABLE 7.2. Lettuce yields in the dry and wet seasons.

	Irrigation method	**No. of samples**	**Fresh weights per plant (kg per lettuce plant)**			**Fresh weights per cropping area (kg m^{-2})**	
			Mean	95% CI	% change	Mean	% change
Dry season	WC	24	0.129	0.128-0.130		1.94	
	FI	24	0.056	0.056-0.058	- 56.6	0.56	- 71.1
	DIK	24	0.142	0.141-0.143	+ 10.1	1.85	- 4.6
Wet season	WC	24	0.147	0.146-0.149		2.21	
	FI	24	0.130	0.129-0.131	- 11.6	1.30	- 41.2
	DIK	24	0.158	0.157-0.159	+ 7.5	2.05	- 7.2

WC = watering cans; FI = furrow irrigation; DIK = drip irrigation kits

Source: Keraita et al. (2007a).

Farmers' Perceptions of Irrigation Methods

In the field trials done by Keraita et al. (2007a), in Kumasi, farmers generally used more water and more labor on furrow irrigation plots due to their sandy texture and were quite negative about the method. Drip kits were more appreciated, in particular because of the physical quality of the lettuce produced. As water reached the root zone directly, foliar injury or soil splash on the leaves were avoided. In general, the drip kits used much less water and saved time and labor costs. Farmers also noticed that the average size of lettuce was much bigger while weeds did not receive water and were suppressed more effectively. The biggest limitation of the kits was some occasional clogging and the wide emitter spacing, especially with initial drip kits which only supported low cropping densities and thus resulted in very low yields which is not acceptable in space-constrained urban farming.

Though modifications of drip irrigation kits have improved cropping densities, farmers had problems in moving the increased number of drip laterals and microtubes while conducting other farm operations like weeding, land preparation and manure application. In general, farmers appreciated drip irrigation kits but said it was important to modify them to fit their practices. In addition, farmers suggested that drip kits might be better suited for other crops like water melon and green pepper that take a longer cultivation time and need wider spacing. The general perception by farmers was that their watering can method remained the most flexible and thus most suitable method for irrigating vegetables like lettuce. This conclusion appears to hold across the subregion (Drechsel et al. 2006).

7.5 Options and Constraints to Technology Change

Having to spend a significant share of time on manual irrigation (see chapter 4) farmers have a natural interest in less laborious but low-cost irrigation methods that can reduce their workload. However the continued use of arduous methods of irrigation in urban agriculture, even when newer technologies are available, raises the question of the reason why improved methods are not more widely used.

In Accra, farms are often found along streams and drains, and are at best tolerated by the authorities. The conveyance distance when using watering cans is usually short enough to favor labor over capital input. Watering cans allow more flexibility, one-man-usage and are less sensitive to bad water quality and solids. Moreover, they allow ‘soft’ water application, protecting young vegetables on their beds. All these are good reasons to avoid investment in pumps and hoses. In addition, there are differences in the related input markets (also for pumps and hoses). EnterpriseWorks, started promotion of treadle pumps in most Francophone countries of West Africa between 1995 and 1999, while corresponding activities in Ghana only started in 2002 (Adeoti et al. 2007). However, the latest assessment showed that the initiative of treadle pumps in Ghana was not successful compared to the rapid uptake of small motor pumps (Namara et al. 2014).

A comparison with neighboring Lomé, Togo, where farmers cultivate high value crops for export on poor quality beach sands using motorized pumps, shows that there is a combination of factors involved, which goes beyond the higher investment and maintenance costs of such technologies. Farmers in Lomé have access to larger plots, and the city authorities accept them (Figure 7.5). In many cases, tenure agreements exist. This security favors investments, for example, in tube-wells to access safe water and multiple storage ponds, i.e. conveyance-saving technologies, which are necessary to maximize the profits from larger plots.

FIGURE 7.5. Watering can irrigation with well, pump and storage reservoirs in Togo. Other reservoirs are visible in the background (photo: IWMI).

Thus it appears that technology promotion has to consider a variety of local conditions, both biophysical and socioeconomic. Shallow wells and watering cans may be the most appropriate technology, for example, in Kumasi's inland valleys. The demand for motor pumps might, however, rise on upland sites, and in Accra, especially where farmers can share one pump and the water sources are not too close. Pumps might be tried where groundwater is available between 1 and 7 m or the walking distance between field and water source is more than 50 m. If the pump is not mobile, the farm site needs facilities to secure the pump overnight as farmers might live far from their fields. In general, many farmers prefer using small motorized pumps in combination with watering cans for water lifting and application. Wherever there is better water quality than in drains, low-cost drip irrigation technologies like bucket-kits and drum-kits, could be tested. These might fail without filters where wastewater is used. For drip systems, lateral and emitter spacing has to fit farmers' normal cropping densities or adoption will be low. The authorities should support these changes, which could reduce the health risk associated with using polluted water, like sedimentation ponds, and changes in irrigation practices. Tenure security could be an incentive for farmers to invest in recommended practices.

7.6 Soil Fertility Management Practices

Nutrient Management Practices: Irrigated urban vegetable farming in Ghana is intensive and often year-round, hence significant amounts of nutrients are exported with each harvest (Drechsel and Zimmermann 2005). On such poor soils, corresponding external inputs are needed. In the more humid parts of West Africa, farmers prefer poultry manure due to its high nutrient content coupled with its fast release of nutrients for vegetables with short growing periods, and usually low price (Zickermann et al. 1998; Drechsel et al. 2000). Poultry manure is also favored due to its narrow C/N ratio. The ammonium (NH_4)-N and uric acid-N content of poultry manures equate to the readily-plant-available-N supply. Adding manure to the soil has agronomic benefits through the addition of plant nutrients (such as nitrogen, phosphorus and potassium [NPK]) but also as a soil ameliorant through its organic matter contents, similar to compost. Manure like compost thus also helps to improve soil structure, water-holding capacity, soil stability and biological activities.

A survey conducted among 108 farmers of different urban cropping systems in Accra showed that there were clear differences in the type of soil fertility management used in the different systems (Hofny-Collins 2006). Farmers specialized in rainfed crops, like maize, relied on traditional low external input measures such as fallowing, crop rotation and crop residues with some limited input of artificial fertilizer and chicken manure. The year-round vegetable growers relied heavily on external inputs for soil fertility maintenance. The survey showed that almost all (93%) used poultry manure and over half (56%) used artificial fertilizers, though not on every crop (Figure 7.6). NPK 15-15-15 is applied for example at rates of 75-180 kg/ha^{-1} per year on cabbage, the exact amount depending on the farmer’s experience and the soil. Next to manure and chemical fertilizer, vegetable growers used a whole range of other techniques supporting soil fertility and it was common for individuals to use a combination of three to five techniques. Vegetable farmers in this survey said as a fertility input, normal municipal waste compost was *inferior*, particularly in relation to crop establishment and as it created a higher irrigation demand because the compost absorbed the water (Hofny-Collins 2006). Without adding nutrients to compost (for example co-composting with fecal sludge, or blending with NPK) the wide C/N ratios make it more of a conditioner for soil structure than a fertilizer, which might decrease its attractiveness for farmers with limited tenure security.

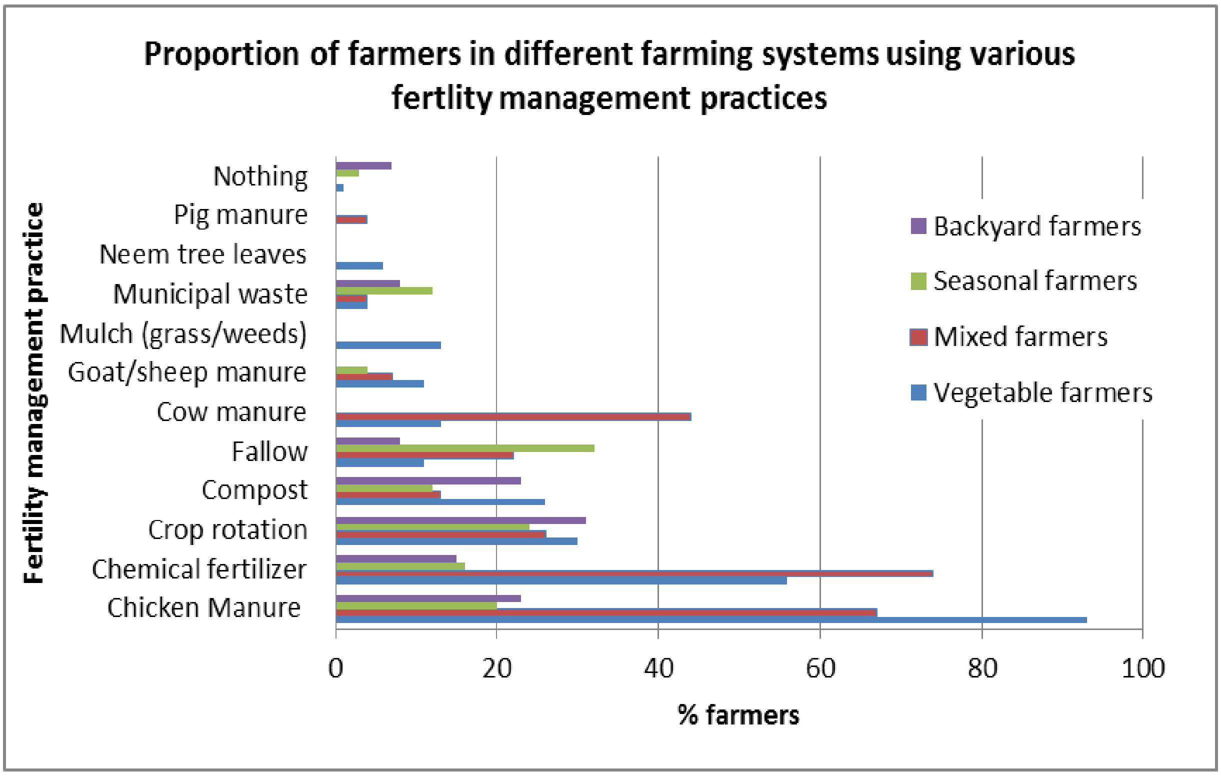

FIGURE 7.6. Fertility management practices in Accra, Ghana (based on 108 farmers). Adapted from Hofny-Collins (2006).

The use of poultry manure is very common in Kumasi where initially it was considered a waste product of the poultry industry and dumped or burned along roadsides (Quansah et al. 2001). Farmers said that in comparison with chemical fertilizers, poultry manure is cheaper, releases nutrients much slower and is a much better soil conditioner. However, its quality can vary depending on its age and source (broilers vs. layers) (Drechsel et al. 2000). Reported poultry manure application rates vary widely among sources and might range from 7 to more than 20 t ha^{-1} for exotic vegetables (Poferl and Keraita 2008; Erni et al. 2010). The application is done manually one week after transplanting. Farmers in Northern Ghana where the lower humidity does not support larger poultry farms, use relatively more kinds of manure from livestock such as cows, goats and sheep, next to chicken droppings.

The use of poultry manure as a fertilizer seems to be quite widespread in West Africa, and its supply is supported by changes in diets making poultry an increasingly common fast food ingredient in the present-day context (see chapter 5). However, poultry manure has to be managed appropriately as it contains a wide range of bacteria, viruses and protozoa, some of which are pathogenic and can have adverse effects on people (Mensah et al. 2001). *Salmonella* spp., *Campylobacter* and *E. coli* are the most common pathogens found in poultry manure (AWWA 1999). Most of these pathogens can survive in soils and manures for more than a month, but generally the survival rate is lower (one to seven days) in dry conditions. Proper manure composting can greatly reduce levels of pathogens (a manure pile can be a first step) while nitrogen loss should be controlled. However, as demand for the manure is increasing it is often not stored/composted long enough before application to allow for pathogen die-off. Studies done in Kumasi show that after collection, about 60% of the farmers apply the poultry manure directly without further composting while 40% heap the manure for some weeks or more depending on the date they need it on their fields (Mensah et al. 2001). Other than direct contact when spreading, manures can contaminate soils and then be transferred to vegetables. Studies done in urban vegetable farms in Ghana have shown higher contamination levels in soils than in irrigation water (Amoah et al. 2005; Keraita et al. 2007ab). Amoah et al. (2005) also associated vegetable contamination with contaminated soil splashing on the leaves of low-growing vegetables and suggested mulching to prevent this, hence reducing levels of contamination on vegetables.

Another input which is highly valued, although more among flower or ornamental farmers is ‘black soil’ (Cofie et al. 2008). With ‘black soil’, farmers in Ghana refer to dark, humus-rich topsoil as it can be found in undisturbed forests and decomposed waste dumps, like the community based ‘bola’ sites. Black soil harvested from local waste dumps, agricultural land and forest for horticulture, gardening and landscaping is very common and the material is highly regarded for its quality. However, the continuous harvesting of black soil makes it increasingly difficult to find it while its removal from natural soils has a strong negative impact on the environment (Danso et al. 2006).

Since 2010, biochar[1] receives increasing attention in Ghana, although so far mostly from research, including the UrbanFoodPlus project (www.urbanfoodplus.org). Biochar from rice husks, sugar cane residues or for example wood chips and saw dust is being tested with different crops, including indigenous and exotic vegetables in the Volta region and the Accra plains on clayey soils, on red soils in Kumasi (Yeboah et al. 2013) and on sandy loams near Tamale. Also the seasonal use of ‘human manure’ (fecal sludge delivered to the farms through septage carrying trucks) has been reported from peri-urban farming, particularly of maize and other cereals but not vegetables. The practice is most common around Tamale but has also been observed in other parts of Ghana (Cofie et al., 2005; Cofie et al. 2010) including the La area in Accra (see the CD attached to this book).

[1] Biochar is charcoal that is used for specific purposes, typically soil improvement. It is produced by heating biomass, like rice husks under anoxic conditions (pyrolysis).

Wastewater as a Nutrient Source: Farmers able to tap into raw wastewater (e.g. Accra's La area, Tamale's Kamina area) and experience its nutrient value, try to consider it in their soil fertility management. Most farmers, however, use diluted wastewater or polluted stream water with too low nutrient levels to build on this input in their decisions to fertilize crops. As the water-derived nutrient concentrations vary also with dilution, distance from the wastewater source, over the day and between seasons, it is nearly impossible for farmers (who cannot pay laboratories) to predict the nutrient content. Thus most farmers rely on manure, and irrigate depending on crop water needs and not nutrient needs.

In terms of N and P, the fertilizer input from wastewater was estimated by Erni et al. (2010) to account for only about 10% of what is applied via other fertilizers where diluted wastewater is used along the Oda River which absorbs most of the wastewater generated in Kumasi.

The generally high nutrient input via manure is justified when the number of growing periods over the year is considered, i.e. high frequency of harvests which are significantly contributing to nutrient exports from the farm. The losses are even larger through nutrient leaching, especially where soils are sandy and regularly irrigated. Preliminary nutrient balance assessments indicate negative N and K balances while phosphates might accumulate in the topsoil. However, as long as nutrients are supplied at very low costs (especially via poultry manure) and land tenure is insecure farmers do not see the need for long-term nutrient management which is in addition likely to only result in higher direct or indirect costs.

7.7 Conclusions

Streams, drains and shallow wells are the most common sources of irrigation water. Watering cans are predominantly used for good reasons, but make the task arduous. However there is increasing use of small motorized pumps in Ghana, used either to shorten water transport distances, or directly linked to water application. Improving irrigation efficiency – not only to save water where water is scarce, like in Tamale, but also where irrigation consumes too much labor and puts extra burden on irrigators should receive more research attention, ideally combined with options for health risk reduction.

Nitrogen rich poultry manure continues to be the preferred fertilizer for leafy vegetables. Initiatives of using other soil ameliorants like compost were received with hesitation due to limited nutrient content, bulkiness and (too high) water absorption. Municipal solid waste compost is usually poor in nutrients and it falls short if compared with 'black soil' or manure, unless it gets blended (fortified) for example with NPK, fecal sludge or urine (Adamtey et al. 2009; Nikiema et al. 2012). Without this, soil ameliorants with long term benefits like biochar and compost appear more relevant for cereals and farms with protected land tenure.